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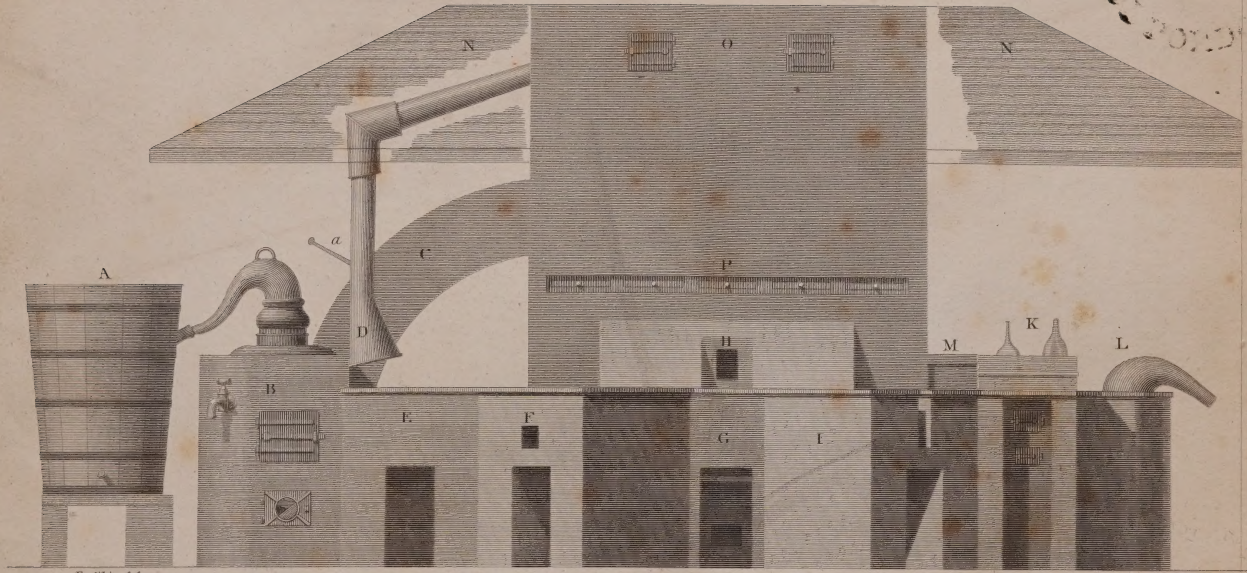

E. Atkin del.

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Arrangement of the Furnaces in Mr. Pepys's Laboratory.

LONDON MEDICAL SOCIETY

A

DICTIONARY

OF

CHEMISTRY AND MINERALOGY,

WITH AN ACCOUNT OF THE PROCESSES EMPLOYED

IN MANY OF THE MOST IMPORTANT

CHEMICAL MANUFACTURES.

TO WHICH ARE ADDED A DESCRIPTION OF

CHEMICAL APPARATUS,

AND VARIOUS USEFUL TABLES OF

WEIGHTS AND MEASURES, CHEMICAL INSTRUMENTS, &c. &c.

ILLUSTRATED WITH FIFTEEN ENGRAVINGS.

BY A. & C. R. AIKIN.

VOL. I.

LONDON:

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AND WILLIAM PHILLIPS, GEORGE YARD, LOMBARD STREET.

1807.

(W. PHILLIPS, PRINTER.)

TO

CHARLES HATCHETT, Esq. F.R.S. &c.

WHOSE ADMIRABLE RESEARCHES IN THE SCIENCE

WHICH IT IS THE OBJECT OF THESE VOLUMES TO EXPLAIN,

HAVE RAISED HIS NAME TO AN EXALTED STATION

AMONG ENGLISH CHEMISTS,

THIS WORK

IS RESPECTFULLY DEDICATED, BY

THE AUTHORS.

PREFACE.

In ſubmitting to the Public a Work of conſiderable magnitude, the labour of ſome years, the Authors claim the uſual indulgence of pre-engaging the notice of their Readers with a few words on its plan and object.

Their intention has been to give a faithful and ſufficiently detailed deſcription of all the important facts hitherto diſcovered in the ſciences of Chemiſtry and Mineralogy, enlarging more particularly on thoſe parts which are of peculiar intereſt to the Manufacturer and to the Practical Chemiſt.

Both the advantages and defects of the form of a Dictionary are ſufficiently felt to render needleſs any obſervations on this ſubject; and the great encouragement which has been given in this and in other countries to this plan of deſcribing the Arts and Sciences, is an ample proof of its utility and general acceptableneſs.

Though the compaſs of two quarto volumes would appear to allow ample ſpace for a compleat deſcription of every branch of this ſcience, the authors were convinced that they ſhould either have been cramped in the parts on which they wiſhed to enlarge, or have been compelled to extend their work to an inconvenient length, without ſome previous ſelection of the overflowing matter which lay before them. They have therefore omitted (not as being leſs intereſting in itſelf, but merely as leſs ſuited to their particular purpoſe)

every thing relating to Geology, to the application of Chemiſtry, to Medicine or Phyſiology, to Galvaniſm, and to the Hiſtory of the ſcience, except to reclaim the merit of diſcovery in a few diſputed inſtances for thoſe to whom it appeared to be juſtly due; and they have made it a general rule to touch very ſlightly on the theoretical part of chemiſtry, that they might dwell on the practical. To render their labours uſeful as a *Laboratory Guide*, they have been ſtudiouſly minute in moſt deſcriptions of analytical proceſſes and elementary experiments, and they truſt that their readers will not regret the pains that has occaſionally been taken to reconcile the varying reſults of ſuch chemiſts as Prieſtley, Klaproth, Kirwan, or Vauquelin, not by impeaching their general fidelity, but by ſhewing the inaccuracy of data on which their calculations have been founded.

With regard to the deſcription of Chemical Arts and Manufactures, the intention of the authors of this work is not (had they the means) to teach their readers how to become iron ſmelters—glaſs-makers—ſoap-boilers—dyers—but to deſcribe, as fully as they were able with the materials before them, the general principles on which theſe and other important chemical arts are carried on (with which the manufacturer himſelf is often but imperfectly acquainted) and by exhibiting the rationale of theſe proceſſes to ſhew what parts of them offer the moſt reaſonable probability of improvement.

Some new or hitherto unpubliſhed matter will be found interſperſed in theſe volumes, and particularly ſpecified in the notes of reference to the reſpective articles. It relates chiefly to the deſcription of certain manufactures, ſuch as the ſmelting of copper, iron, and tin; the making of vitriol, common ſalt, ſal ammoniac, and a few other proceſſes, on which ſubjects the authors have been

favoured with original communications from friends on whoſe accuracy they can fully rely. They have alſo added the reſults of their own experiments on a few detached ſubjects that have engaged their attention.

The nomenclature which they have uſed has been in general that which is now become the vernacular tongue of ſcientific chemiſtry; but they have not in the leaſt degree ſcrupled to blend it with the chemical language of Bergman, Scheele, Black, Beaumé, and a croud of other excellent chemiſts, whoſe works are rich with ever-valuable facts, and whoſe terms are ſtill retained in ſhops and laboratories.

Such is the work now offered to the Public. They who have been engaged in ſimilar purſuits will be able juſtly to appreciate the labour required in ſelecting, arranging, and comparing materials from voluminous tranſactions of learned ſocieties, from long ſeries of periodical works, and from the copious ſtore of individual or elementary treatiſes with which this ſcience abounds. The original authorities have been uniformly reſorted to whenever the authors have had acceſs to them, and when they have been obliged to uſe the medium of a Journal or Tranſlation, care has generally been taken to expreſs it in the notes of reference. By this means the reader may readily go over the ſame ground, and the Authors flatter themſelves that ſuch an examination will turn out favourable to the character of accuracy and impartial fidelity which it has been a principal object with them to acquire.

ERRATA in VOL. I.

Page 20,	line 11 *from the bottom*,	*for* greyiſh clay,	*read* greyiſh ſlag.
41,	14 *from the top*,	*for* durability,	*read* ductility.
57,	8 *from the bottom*,	*for* unbedded,	*read* imbedded.
118,	8, 10, 11, 12, *from the top*,	*for* × put	+
120,	4 *from the top*,	*for* meaſures	*read* increaſes.
——	11 *ditto*,	*for* deſcends	*read* aſcends.
127,	2 *from the bottom*,	*for* or,	*read* of.
169,	25 *from the top*,	*for* it in,	*read* in it.
237,	24 *ditto*	*for* with azot,	*read* with hydrogen.
——	26 *ditto*	*for* hydrogen,	*read* azot.
247,	19 *from the bottom*,	*for* 42.32,	*read* 40.32.
357,	10 *from the top*,	*for* it,	*read* heat.
359,	17 *ditto*	*for* return,	*read* retain.
519,	7 *ditto*	*for* ſtrong muriatic,	*read* ſtrong nitro-muriatic.

ABSORBENTS. ABSORBENT EARTHS.

The ancient chemists were accustomed to use the term Absorbents in a general sense, to denote all the alkaline, and such earthy bases, as were capable of absorbing or neutralizing acids. Chalk, magnesia, and clay, were however principally distinguished by this name, both on account of their easy combination with acids, and their mechanical absorption of water, and such other fluids as they do not combine with. Modern chemistry has almost discarded the term.

ABSTRACTION. *Abziehen*, Germ.

The process so called, consists in drawing off, by distillation, part of a compound, and returning it again, on the residue to be thus distilled over any number of times. It is used particularly in oxydating or acidifying substances by means of nitrous acid: thus, arsenic acid may be procured by abstracting arsenic with nitrous acid.

ACETOUS ACID. *Acid of Vinegar. Acide Acteux*, F. *Essigsaure*, G.

As this important acid is, for the most part, though not always, the product of a fermentation consequent to the vinous, and formed of the same general materials, we have referred to the articles *Fermentation* and *Vinegar*, the description of the process of vinegar-making, and the rationale of this operation, and the domestic uses of this acid; we shall here therefore describe the chemical properties of the pure acetous acid, with its varieties and combinations.

The physical properties of pure acetous acid are the following: it is perfectly clear and colourless as water; its smell and taste refreshing and agreeable; and more or less sour and pungent according to the strength of the acid. The specific gravity of common distilled vinegar is about 1.006, but when concentrated in the method hereafter described, its weight is much greater, and by a particular process it may be brought to a solid and crystalline form.

The sources whence this acid may be procured are very numerous, more so than has commonly been supposed. It is found native in several vegetable juices, particularly in the SAP of various trees,[a] and in that singular native animal acid, the acid of ANTS.[b] It is procured not only from vinous fermented liquors, but from most mucilaginous, insipid, extractive animal or vegetable matters, when they turn sour by spontaneous change. Thus the moulding of starch, of moistened flour of any kind, of animal gelly, and even of urine, and the souring of milk, is in some degree a process of acetification, from the products of which, chemistry enables us to separate a certain portion of this acid, without a particle of alcohol (the test of vinous fermentation) having been generated. The action of fire upon these substances is a more immediate agent to the same effect, the valuable experiments of Fourcroy having proved that the acids of burnt wood, sugar or mucilage, and tartar, (commonly termed the pyroligneous, pyromucous and pyrotartareous) are no other

[a] Vauquelin. [b] Fourcroy.

than the acetous, holding in ſolution a certain quantity of empyreumatic oil.

Laſtly, the action of the ſtronger mineral acids upon the ſame vegetable and animal matters, tends to the production of the acetous acid, which is moſt ſtrikingly illuſtrated by the final converſion into vinegar of all the intermediate and native vegetable acids, the malic, tartareous, gallic, oxalic, &c. The experiments that prove this intereſting fact we ſhall preſently relate.

Pure acetous acid is conveniently procured from common vinegar by diſtillation. The latter contains, beſides acetous acid, a conſiderable quantity of foreign ingredients, ſuch as alcohol, and particularly tartar, and the extractive mucilage, which gives it its red or yellow colour, and cauſes it to mould and loſe its acid when long kept expoſed to warm air. Of theſe the alcohol, the water, and the pure acetous acid, are the only volatile ingredients, and therefore ſeparable by diſtillation. The diſtillation of vinegar is carried on in the large way by the druggiſts, for general purpoſes, and for the preparation of ſugar of lead; in ſome parts of the ſouth of France for the preparation of verdigris;[c] with theſe it is diſtilled in a tinned copper veſſel, as the action of vinegar upon tin is but ſlight. For the laboratory, however, glaſs veſſels ſhould be employed, or if the retort or boiler be of metal, the head or receiver ſhould be of glaſs or earth. The ſtrongeſt common vinegar is to be put into a glaſs retort with a receiver, and brought to boil on a ſand bath. A watery and ſlightly acid vapour firſt condenſes, which is a very weak acetous acid, and may be ſet aſide. Then the diſtilled liquor (ſtill continuing equally clear and colourleſs, but a little empyreumatic in ſmell and taſte) becomes more ſtrongly acid, and continues ſo to the laſt. This is the common acetous acid or diſtilled vinegar. Towards the end of the proceſs, the reſidue is very apt to acquire and communicate a burnt ſmell and taſte: this is prevented by carefully regulating the fire, and, if it be worth while, by adding to the liquor in the retort a little warm water; but when about five-ſixths of it is diſtilled, the proceſs ſhould be diſcontinued. The reſidue is very ſour, of a muddy brown red, and a ſtrong pungent burnt ſmell. It contains, beſides the remaining acetous acid, ſome tartar, and tartareous acid, and a ſlimy vegeto-animal matter, which has not been perfectly analyſed. By further evaporation it becomes thick, tenacious, and at laſt a ſolid blackiſh extract. On urging the fire to deſtructive diſtillation, it gives a ſour empyreumatic inflammable vapour, an empyreumatic oil, and ammonia. The coal contains potaſh, mixed with a ſubſtance which gives oxalic acid in cryſtals when boiled with the nitric acid.[d] The vapour of heated vinegar, or the acetous acid gas, as it has been termed, is inflammable.

The truly acid part of the purified acid is ſtill mixed with a large portion of water. Means have been deviſed for condenſing or concentrating the acid in a ſmaller bulk. Diſtillation alone, as we have ſeen, is not competent to this purpoſe; for, though ſome of the water riſes nearly pure juſt at firſt, yet it ſoon becomes very ſour, as the acid is almoſt equally volatile by heat as water.

The effect of froſt in concentrating vinegar is very ſtriking. If a quantity of this acid, diſtilled or not, be ſet out in the air in winter, when the cold is below about 26° a tender flaky ice forms in the liquor, and renders a large portion of it ſolid; on breaking it, a portion, ſtill fluid, is found beneath, which is to be carefully drained off from the ice. This fluid is the acetous acid, concentrated by the loſs of all the frozen part, which laſt is taſteleſs or very nearly ſo, and is little elſe than pure water. A further expoſure of the ſtrong acid to a ſharper cold, will produce a ſimilar and encreaſed condenſation, till at laſt the proceſs muſt be ſtopped, either on account of the cold not being now ſufficient to ſeparate the water from the conſtantly ſtrengthening acid, or from the ice itſelf becoming acid. Diſtilled vinegar may be brought by this mode of concentration from the common ſpecific gravity of 1.006 to that of 1.029.[e] In this ſtate it ſtill retains the phyſical properties of the watery acid, but in a much more exalted degree; its ſmell is ſtrongly and agreeably pungent; its taſte ſharp, almoſt to cauſticity; and as a chemical agent, it is much more active and powerful in every reſpect. Common vinegar is equally ſtrengthened by freezing, but as the colouring matter chiefly remains in the unfrozen part, it becomes more highly tinged as the more condenſed.

A more effectual mode of concentrating this acid is by previous union with an alkali, an earth, or a metallic oxyd, and bringing it by evaporation to a ſolid conſiſtence. In ſo doing, all the ſuperfluous water of the acid is ſeparated, and if the acid be afterwards expelled from the ſalt by means of a ſtronger affinity, it appears in the moſt concentrated form of which it is

[c] Chaptal. [d] Gren. (Syſtem. Handbuch.) [e] Own Exper.

capable. Considerable difference of opinion has arisen whether the nature of the acid is essentially changed by this operation, or whether it is simply dephlegmated to the highest degree. This we shall afterwards notice, but we may observe that it is chiefly to its union with metallic oxyds that this question applies.

The first process of this kind was invented by Westendorf. It is the following:[f] saturate pure distilled vinegar with mild soda, filtre the solution, evaporate to a syrupy consistence, and suffer the acetited soda to crystallize. Dry the salt thus obtained, powder it, put it into a tubulated retort luted to a large receiver, add half its weight of strong and quite colourless sulphuric acid, and distill on a sand bath with a gentle heat, nearly to dryness. If it rises mixed with sulphuric or sulphureous acid, redistill it off a little clean clay.

This acid, which the inventor terms *alcohol aceti*, or *radical vinegar*, is excessively volatile and pungent, and also inflammable. However, it always contains sulphuric and sulphureous acid, from which it may be separated with great ease, by adding acetited barytes, as long as any white precipitate falls down.

The acid thus highly concentrated is crystallizable by cold. The Count de Lauraguais procured it glacial, when obtained from verdigris, in the way we shall presently mention; but Lowitz's experiments are still more curious.[g]

This chemist first concentrated common wine vinegar by severe frost, distilled this in a water bath, surrounding the receiver with ice, and retaining only the latter portion of the product, which was by much the strongest. This last he redistilled from off some charcoal powder, to free it from empyreuma. This concentrated acid he exposed to the intense cold at Petersburg, of —22° Fahr. when part of it shot into crystals, leaving the rest uncongealed. These crystals when separated from the liquor, melted in a warm chamber, into an intensely caustic acid, which now, when again exposed to cold, congealed into a camphor-like white mass.

On account of the intense cold requisite for this process, it cannot be performed exactly in this manner in our climates; but the author gives another method which answers as well.

Mix and put in a retort two parts of dry acetited soda, with eight parts of dry crystallized *acidulous* sulphat of potash, and distill with a gentle heat. The process goes on speedily even in a weak fire, and two parts of a very strong acetous acid are obtained. By this method no contamination with sulphuric acid is to be feared. This acetous acid in a temperature of about 38°, or a little higher than freezing water, shoots into either fine arborescent feathery crystals, or else into a confused striated mass. It remains unthawed till about 59°. It is much stronger than Westendorf's vinegar, is inflammable when gently heated and a lighted paper held to its surface, and burns with a gentle blue flame.

The acetous acid in every form, whether free or in combination, is completely decomposed by a low red heat, its acid properties destroyed, and it is reduced into its constituent parts; or rather, these parts form new combinations, from which the analysis of this acid may be satisfactorily inferred. The base or radical of the acetous acid appears to be compounded of carbon and hydrogen, mixed with a small quantity of azot. Hence it is that when the vapour of this acid is passed through a red hot earthen or glass tube, carbonated hydrogen, and carbonic acid gasses, are generated in great abundance, and, owing to the presence of the azot, a small quantity of ammonia generally appears whenever this acid is exposed to destructive distillation. The combustion in close vessels of the dry acetites affords a similar proof of the composition of this acid. In an experiment made by Dr. Higgins,[h] a quantity of acetite of lime, long dried in a heat of 212°, and giving no smell of acetous acid, was exposed to a gradual dry and destructive distillation, in an earthen retort, till the vessel was red hot, and every thing volatile in this heat was given out. After a small quantity of azotic gas had first come over, the products were carbonic acid gas, carbonated hydrogen, etherial oil, and aqueous vapour: the etherial oil passed off from the beginning, the carbonic acid throughout, and the carbonated hydrogen chiefly towards the end. The residue in the retort consisted of lime combined with much carbonic acid (which portion therefore had become fixed), and also blackened with some charcoal. On account of the variety of affinities which may readily be supposed to be mutually exerted on these easily combinable materials, at the impulse of caloric, the precise state and proportion of these ingredients, as they existed in the acid, cannot be deduced from the experiment, and even the presence of oxygen (independently of that existing in the water) would here be inferred only from the general analogy of acids. The carbonic principle is obviously the most prominent

[f] Syst. Handbuch. [g] Crell. Annal. [h] Minutes, &c.

ingredient in this rough analyſis, appearing in a variety of forms, both ſeparate and combined.

The chemical compoſition of acetous acid is beautifully illuſtrated by the agency of the ſtronger mineral acids, both upon the hydro-carbonated baſes of ſome of the other vegetable acids, and upon theſe acids themſelves. Weſtrumb firſt diſcovered, that the acids of tartar and ſugar, when boiled with nitrous acid, are converted into vinegar. The experiments of Hermbſtaedt on this ſubject are highly intereſting and inſtructive.

It had been diſcovered by Scheele, and confirmed by others, that ſpirit of wine, when treated with nitrous acid, was partially convertible into the tartareous and oxalic, or ſaccharine acids. Mr. Hermbſtaedt examined this point with more attention. [1]

He began by paſſing oxymuriatic acid gas from a pound of manganeſe, and a pound and a half of common muriatic acid, through a pound of highly rectified alcohol, which abſorbed all the gas, and thereby became enlarged two-thirds of its bulk, and acquired a ſtrong odour of nitrous ether. This was diſtilled till the product began to be acid; the reſidue was ſaturated with potaſh, and gave by evaporation muriat of potaſh and acetite of potaſh. Thus the production of the acetous acid from ſpirit of wine was proved, but to ſhew whether or not the alcohol previouſly contained any vinegar, further experiments were made. He took the gummy reſidue, left after the diſtillation of nitrous ether, or nitrous acid and alcohol, boiled it with ſome nitric acid, and obtained from the mixture much tartareous acid. Seven drams of this concrete acid were then diſtilled with one and a half ounce of nitrous acid; the diſtilled liquor was reſerved, and the reſidue contained four drams of a concrete acid, which was now no longer tartareous, but chiefly ſaccharine acid. On twice repeating this proceſs with the ſame quantity of nitrous acid, only half a dram of ſaccharine acid remained in the retort. All the liquors of the ſeveral proceſſes were then re-diſtilled together, and the product gave now only ſlight ſigns of ſaccharine acid, but when ſaturated with potaſh produced acetite of potaſh. Again, on dropping carefully one part of alcohol on three parts of nitric acid, much heat was excited, and bubbles of gas aroſe, which were chiefly carbonic acid, ſmelling ſtrongly of vinegar. The ſame chemiſt varied theſe experiments in the following manner: two parts of dry acid of tartar were mixed with four parts of manganeſe, and three of ſulphuric acid, and diſtilled. The product was acetous acid mixed with the tartareous: on re-diſtilling it on the ſame materials, no other than acetous acid was now obtained. A ſimilar reſult was given by oxalic acid, manganeſe, and ſulphuric acid. Without the manganeſe the product is ſulphureous acid, owing to the partial decompoſition of the ſulphuric, mixed however with the acetous.

The experiments of Dr. Crell are ſo ſimilar to theſe above related, that we need not deſcribe them particularly. In all, the acetous acid was produced in the way above mentioned, from the ſame materials.

The inference from theſe curious experiments is, that the radical of the tartareous, and oxalic, and we may add of many of the other vegetable acids, is the ſame, and that it exiſts in alcohol as well as in the native juices from which theſe acids are obtained. It is doubtleſs a compound of carbon and hydrogen, in certain unknown proportions. They are convertible into vinegar by the agency of the nitrous or the ſulphuric, or the oxymuriatic acid, the operation of which the antiphlogiſtic theory will aſcribe to the addition of oxygen, and perhaps at the ſame time the abſtraction of a certain portion of the carbonaceous principle, which eſcapes in the form of carbonic acid.

We proceed to mention that variety of acetous acid, formerly known under the name of *radical vinegar*, and in the modern nomenclature termed (by ſome at leaſt) ac*etic* acid, in contradiſtinction to the ac*etous*. It is procured by diſtillation of the metallic acetous ſalts, more eſpecially the acetite of copper, or *diſtilled verdigris*; though there is much reaſon to ſuſpect that the highly concentrated vinegar obtained by Weſtendorf's and Lowitz's method, from the alkaline acetites as above deſcribed, reſembles the radical vinegar in every eſſential particular.

This may be procured in various methods: the following is the moſt ancient—Put any quantity of cryſtallized verdigris (commonly called *diſtilled verdigris*) reduced to powder, in a glaſs retort, with a large glaſs receiver; apply heat, gradually increaſing, till every thing volatile has come over. The firſt product is a mixture of carbonic acid and hydrogen, about one-ninth part of the weight of the cupreous ſalt; [2] then appears a watery liquor a little ſharp to the ſmell, but preſently it becomes more and more acid, and at laſt exceſſively pungent and cauſtic, and of a greeniſh hue and ſomewhat

[1] Crells. Chem. Annal. 1786.—J. Phy. Tom. 31. [2] Darracq. An Ch. T. 41.

coppery ſmell. This is the true radical vinegar, which ſhould be kept apart from the former product in a well cloſed bottle. The reſidue is a red-brown oxyd of copper mixed with charcoal, which when the retort has been made red hot, to drive out the laſt portions of acid, often lines the inſide with a cupreous metallic-looking pellicle. This oxyd is ſometimes pyrophoric.

Another and more economical proceſs is the following, given by M. Badolier:[k] mix equal parts of ſulphat of copper and acetited lead, diſtill as the laſt, but with a more gentle fire. A very pleaſant and extremely pungent radical vinegar comes over, about a third of the weight of the ingredients uſed.[l] No gas, except the atmoſpherical air of the veſſel, is given out in this proceſs, which is eſſentially the ſame as the former, ſince the perfect acetite of copper is firſt produced by the mixture of the two metallic ſalts, which mutually decompoſe each other, as ſoon as their affinities can begin to operate. The acetic acid procured from the ſalts of copper, is diſtinguiſhed by a light greeniſh colour and a coppery ſmell, which makes an unpleaſant addition to the agreeable pungency of the acid. It is not neceſſary to cryſtallize the verdigris in the firſt proceſs, a ſolution of oxyd of copper in vinegar evaporated to dryneſs, will anſwer the ſame purpoſe. An acid ſimilar at leaſt in moſt ſenſible properties, may be obtained from the acetite of lead, not indeed by diſtillation per ſe, but by the addition of ſulphuric acid, for none of the metallic, or alkaline, or earthy acetites, that have been ſubjected to experiment, will yield their acid, undecompoſed by ſimple diſtillation, except the acetite of copper. Six ounces of ſulphuric acid, added to twelve ounces of ſugar of lead, and diſtilled with a gentle heat, will give ſeven ounces of a very concentrated cauſtic vinegar.[m] In this however, as in moſt of thoſe proceſſes where the naked ſulphuric acid is added, the product is contaminated towards the end of the diſtillation, by ſulphureous gas ariſing from the partial decompoſition of the acid by part of the carbonaceous baſis of the vinegar.

Many experiments have been made, and arguments adduced, on the queſtion of the difference of the acetic and acetous acids, but further facts are ſtill wanting to enable us to decide with certainty. It appears reaſonable that in making the compariſon, we ſhould only conſider as proper acetous acid, ſimple diſtilled vinegar, either in its common or watery ſtate, or at moſt concentrated by froſt, which to all appearance makes no other change than that of depriving it of a portion of its water. The acid, concentrated by diſtillation in any form whatever, either from the alkaline or metallic acetites, or by charcoal, or by the aſſiſtance of ſulphuric acid, may probably be conſidered as the acetic, or radical vinegar, in one variety or other.

Diſtilled vinegar, ſtrengthened ſimply by the freezing of its watery part, differs from the acetic acid of verdigris in the following ſenſible properties: its ſmell, though powerful, is much leſs pungent and ſtimulating, the vapours of the latter being ſo potent as almoſt to ſuffocate if ſtrongly ſnuffed up, and to excoriate the noſtrils and mouth: its taſte ſhews the ſame difference of intenſity: its ſpecific gravity is not eaſily raiſed higher than about 1.029, whereas that of the radical vinegar is about 1.0404. When both acids are reduced to the ſame ſpecific gravity by diluting the radical vinegar, the above difference in ſenſible properties is not very perceptible (the adventitious odour of copper in the radical vinegar prepared from verdigris, always being put out of the queſtion) though ſome chemiſts aſſert that it is ſtill to be remarked.

When ſaturated with either of the fixed alkalies, and brought to cryſtallize, the appearance of each ſalt is preciſely the ſame. If an equal quantity of each be ſubmitted to deſtructive diſtillation, the volatile products are ſo nearly the ſame as to allow of no aſſignable difference. However, the quantity of carbonaceous reſidue, according to Chaptal,[n] is leſs in the ſalt with acetic acid (or what, to avoid confuſion, we ſhall for the preſent call the *radical* ſalt), than in the acetous; being only $\frac{1}{17}$ of the original weight in the former, and $\frac{1}{13}$ in the latter. But the experiments of Darracq,[o] conducted in the ſame manner, are not ſo concluſive. Neither of theſe acids have any action on metallic copper immerſed in them; the oxyd of this metal is diſſolved by both, and furniſhes a ſimilarly cryſtallized metallic ſalt; with this notable difference however, that the radical acid diſſolves the oxyd with much more facility, and the ſolution cryſtallizes much ſooner and eaſier.

The acetous acid is in no degree changed by diſtillation with nitrous or oxymuriatic acid, ſo that it does not appear to be ſuſceptible of a higher degree of oxygenation whilſt in the

[k] An. Ch. Tom. 37. [l] An. Ch. Tom. 41. p. 273. [m] Dolfus, Pharm. Ch. Erfahrungen. [n] An. Ch. Tom. 28. [o] An. Ch. T. 41.

form of vinegar. Radical vinegar is equally unchanged by this proceſs.[p] Theſe and other experiments ſeem to decide the queſtion, that the difference between the two does not depend on a different degree of oxygenation of the true acid baſe.

From the preſent ſtate of our knowledge on this ſubject, we may take the following opinion as the moſt probable, namely, that acetous acid, though prepared from common vinegar by diſtillation, retains a conſiderable quantity of a ſoluble, mucilaginous, or extractive matter, which, without entering into the compoſition of the acid, or actually adding to its baſe, (though compoſed of the ſame materials) remains diſſolved by the acid into a kind of ſaponaceous compound: that it ſtill adheres to the acid in its various alkaline, earthy, or metallic ſalts, and oppoſes ſome obſtacle to their cryſtallization, but that, when theſe ſalts are expoſed to the action of heat, or of the ſtronger acids in cloſe veſſels, much of this extractive matter is ſeparated from the vinegar either by forming carbonic acid, or by remaining behind in a carbonaceous ſtate, and the acetous acid by this ſeparation only, and not by any hyperoxygenation, becomes converted into the acetic, or radical vinegar. Hence it will follow, that in verdigris for example, the acid before diſtillation is ſtill acetous, but during this proceſs, the adhering carbonaceous extract turns to carbonic acid, by taking oxygen from the oxyd of copper, which laſt therefore is left nearly in the metallic ſtate, whilſt the acetous acid riſes, ſimply freed from the extract which maſked part of its acid properties, and appears in its purer form of radical vinegar.

Concentrated vinegar may be made to unite with alcohol into a true ETHER, though with more difficulty than the mineral acids.

Diſtilled vinegar does not diſſolve any of the true reſins, but has ſome action on the gum-reſins.

It diſſolves the acrid matter of plants, ſuch as of the ſquill, meadow-ſaffron, &c. which is the compoſition of ſome medicinal vinegars. The ſolution is made by digeſting the ſubſtance in ten or twelve parts of vinegar for a few days.

It thickens fat oils, and diſſolves the eſſential in conſiderable quantity when concentrated. Mr. Weſtendorf diſſolved eighty grains of oil of roſemary in four hundred and eighty grains of his radical vinegar. Common diſtilled vinegar has little more action on theſe oils than water. When mixed with the brown empyreumatic oil of burnt vegetable matter, it forms a peculiar modification of this acid, long known under the name of *pyromucous*, *pyrotartareous*, and *pyroligneous* acids. (For this ſee the next article, ACETOUS ACID. *(Empyreumatic)*.

Common diſtilled vinegar has little more action on camphor than water. The concentrated acid however diſſolves it pretty largely. The camphor is moſtly ſeparable again by water.

The ſtrong acid ſparingly diſſolves vegetable gluten. On ſtarch it has no operation. Gum-arabic and the other mucilages readily diſſolve in vinegar. A mucilage made with diſtilled vinegar may be uſed as a cement, like the watery mucilages, and with this advantage, that it is very little ſuſceptible of mouldineſs.

Jelly is firſt coagulated by the affuſion of vinegar, and afterwards diſſolved.

It coagulates the albumen of milk, blood, and ſerum, but does not diſſolve it.

It ſhews a little action on animal gluten.

The uſes to which the acetous acid in its purified ſtate is applied, are not very numerous. The moſt important is in the manufacture of ſugar of lead and verdigris. It is uſed largely in medicine. None of the acetites, beſides thoſe of copper and lead, are employed to any extent, except in pharmacy and in the laboratory.

The teſts to diſcover the preſence of acetous acid in any mixture, are not very obvious or direct. If the ſubſtance to be examined contains the acid in an uncombined ſtate, it ſhould firſt be ſaturated with an alkali, and evaporated very gently to dryneſs. Then the affuſion of a few drops of ſulphuric acid on a ſmall portion of the reſidue, aſſiſted by a gentle heat, will diſplace the acetous, and give the agreeable pungent acid vapour by which this latter is characterized. Afterwards if the quantity of materials be ſufficient, the neutral ſalt may be diſſolved out of the whole reſidue, and cryſtallized, and its nature thus detected by thoſe who are ſkilled in the practical part of chemiſtry.

The order of the affinities of this acid are barytes, potaſh, ſoda, ſtrontian, lime, ammonia, magneſia, alumine, and the metallic oxyds, (ſuppoſed to be in the ſame order as with the ſulphuric acid.)

ACETOUS ACID. *Empyreumatic.*

A great number of vegetable ſubſtances when ſtrongly heated in cloſe veſſels, ſo as to deſtroy their organization and texture, yield, among other products, a conſiderable quantity of a ſtrongly empyreumatic, bitteriſh, pungent, ſour

[p] Darracq. An. Ch. T. 41.

liquor, which is always more or leſs turbid and dark coloured; is incapable of cryſtallization, unites with alkalies, earths, and ſome metallic oxyds, forming, for the moſt part, brown and foul-looking compounds, generally deliqueſcent.

On account of ſome little variety in the taſte, colour, and ſmell of theſe acids, when procured from different ſubſtances, they have long been diſtinguiſhed from each other, and till of late, were conſidered as ſeparate ſpecies.

They are the following:

1. *Empyreumatic Acid of Sugar, Syrupous Acid*, or *Pyromucous Acid*, which muſt be carefully diſtinguiſhed from the acid of ſugar, or oxalic acid, which is quite another ſubſtance. The pungent acid vapour of ſugar, or any ſaccharine matter ſtrongly heated, muſt be familiar to all who have ever entered a ſugar-baking-houſe. Chemiſts have prepared this acid in the following method:

Put into a very large glaſs retort[a] any quantity of pulverized ſugar, of any kind, ſo as to fill only one-eighth of it, as the matter ſwells prodigiouſly in the proceſs; adapt to it a large receiver, not cloſely luted, and heat it gradually on a ſand bath. A vaſt quantity of gas ariſes when the ſugar begins to ſcorch, which is moſtly carbonic acid mixed with an inflammable gas, probably the gaſeous oxyd of carbon. In the receiver is condenſed a weak acid brown liquor, coloured by an oily matter, and alſo apparently fouled by a portion of fuliginous matter volatilized during the diſtillation. The quantity of acid obtainable in this proceſs, varies according to the regulation of the fire, which ſhould at leaſt be puſhed ſo as to make the retort red hot, and to reduce the ſugar to a perfect charcoal, but in general about five-eighths of the weight of ſugar may be obtained of the diſtilled acid.

Gum mucilage, manna, honey, ſtarch, and other mucous or mucoſo-ſaccharine ſubſtances, yield by diſtillation the ſame acid as ſugar.

2. *Empyreumatic Acid of Tartar*, or *Pyrotartareous Acid*, alſo to be carefully diſtinguiſhed from an acid of ſimilar name, but totally different nature, *Tartareous Acid*.

To procure the pyrotartareous acid, diſtill any quantity of cream of tartar in a glaſs or earthen retort, as in the laſt proceſs. The retort here may be half full of the tartar. On raſing the fire very ſlowly, the firſt produce is a limpid acidulous ſomewhat bitteriſh water, after which, as the heat increaſes, a moſt prodigious volume of the inflammable gas is given out, together with a ſtronger acid and more empyreumatic liquid, and at laſt a black oil, and ſome volatile alkali. The whole quantity of liquid acid, procured from tartar in this method, is generally not more than about a quarter of the weight of the tartar, and is not quite ſo brown nor ſo highly empyreumatic as the former acid.

3. *Empyreumatic Acid of Wood, Ligneous*, or *Pyroligneous Acid*.

To procure it, diſtill as before, any quantity of ſhavings of any kind of wood, ſuch as box, guaiacum wood, or beech, and an extremely ſtrong-ſmelling dark-coloured empyreumatic acid liquor is obtained, nearly one-third of the weight of the wood. This acid is ſourer, and alſo much blacker and more empyreumatic than the two former, probably as requiring a ſtronger heat for its production. The acid of wood is obtained in a large quantity near London, from the preparation of charcoal for GUNPOWDER, by diſtilling wood in caſt-iron cylinders. It ſtains the hands deeply, and wood indelibly.

The three varieties of empyreumatic acid above mentioned, are all capable of very conſiderable purification by eaſy methods, and in proportion as they become purer, they loſe their empyreuma, their peculiar taſte and ſmell (and conſequently their characteriſtic differences) till at laſt, when brought into the moſt concentrated ſtate by ſome of the methods in which vinegar is dephlegmated, they all exhibit the characters of acetous acid in ſo unequivocal a manner that no doubt can now be entertained of their identity.

The varieties in the empyreumatic vegetable acids, were long ago thought to be accidental, and they had been referred to a common origin of a vegetable nature; but it is to one of the many valuable ſeries of experiments with which Meſſrs. Fourcroy and Vauquelin have enriched the chemiſtry of organized bodies,[b] that we owe the complete elucidation of this queſtion.

Simple rectification or re-diſtillation in a very gentle heat, and ſtopping the proceſs when the liquor at laſt comes over much coloured, will purify to a very great degree the pyromucous and pyroligneous acids: the latter, by this proceſs, from being a dark coffee-colour, aſſumes the hue of very pale clear brandy. However on long expoſure to light, it again becomes brown, for it retains its empyreumatic character more obſtinately than the others. Charcoal, newly burnt and powdered, has a great effect in purifying all theſe acids: they may be either gently diſtilled off it, or even merely filtered through a ſtratum of it. But the moſt effectual method

[b] An. Chem. Tom. 35.

of purification is by uniting these acids with lime, or a fixed alkali, evaporating to dryness, and then expelling the acid by means of the sulphuric, in the same manner as the concentrated vinegar is prepared. The acid vapour that rises in this process, has now lost its empyreuma almost entirely; has both the strength and the potent odour of radical vinegar; when again united to potash forms acetited potash, which may be obtained white by repeated crystallization, or by charcoal powder, and in short is perfect acetous acid.

The purified acid of wood has even been employed by Mr. Goetling, for the preparation of an acetous ETHER.

It has been mentioned that the colouring and flavouring matter in all these acids produced by fire, wherein they differ from the acetous acid, is an empyreumatic oil of greater or less intensity in taste and smell, which, as well as the acetous acid, is generated by the fire, and rises along with it, particularly towards the latter end of the process of distillation, when the fire is increased. Acetous acid then is a solvent for the dark-coloured empyreumatic oil of vegetable matter, and as a satisfactory proof of this, the above-mentioned French chemists succeeded in dissolving the oil in pure acetous acid, both by distillation, and more simply by merely shaking them together and digesting for a short time, and thus produced an *artificial empyreumatic acid*, sufficiently resembling those formed by destructive distillation.

The important combinations of these acids are so much identified with the acetites that they may be described together.

The pyroligneous acid alone is procured in such a quantity as to be an object for manufacture. At the best it is only an inferior acetous acid, and the difficulty of purifying it will forbid its profitable use in many of the arts to which vinegar is applied. However, as the process for procuring radical vinegar at the same time purifies this empyreumatic acid, it may probably be used for this purpose.

We may add that much of the acid from the distilled charcoal for gunpowder, near London, is employed by calico-printers in forming the acetited iron, used as a mordant, as here the colour and smell of the acid are in no way detrimental.

ACETITES. We shall here describe the salts formed by the union of the acetous acid with the several alkaline and earthy bases.

ACETITE OF POTASH, formerly *Terra foliata Tartari. Digestive Salt of Sylvius. Diuretic Salt. Regenerated Tartar.*

Much pains have been taken to prepare this salt for medicinal purposes, as it is one that demands great nicety of attention to be obtained perfectly white and pure.

Take any quantity of pure carbonated potash,[a] boil it very gently with four or five times its weight of distilled vinegar added gradually on account of the effervescence; evaporate by slow ebullition, adding afresh distilled vinegar, till no more effervescence is excited. Then evaporate the whole slowly to dryness. A brownish uncrystallized salt remains. This is the acetited potash in its common state of purity, sufficiently so indeed for all medicinal purposes; but if it be required perfectly white, it is then to be melted without addition in its own water of crystallization, for a few minutes, over a moderate fire. This at first makes it darker coloured, and separates a black carbonaceous matter. Then re-dissolve the impure salt in warm water, and filter through paper. This solution should now be limpid, the colouring matter being left behind. Evaporate this solution to dryness, very slowly, in a glass or earthen pan, with frequent stirring, and the remaining salt will be nearly white, and is the pure acetited pot-ash. This is a very tedious process, as one pound of the alkali will require, during the evaporation, nearly twenty pounds of vinegar to keep up the state of perfect saturation, the reason of which is, that much of the acid itself flies off with the heat, so that the vapours of this solution smell like those of mere vinegar. Though both the alkali and acid be as pure as can well be taken, the first evaporation to dryness always leaves the salt brown, except it be conducted at the last in the following manner: when the solution is of a syrupy consistence, continue to evaporate with great care, and in proportion as the salt separates from the solution, take it out with a glass or silver spoon, till almost all of it is thus obtained. This will be white. Mr. Lewitz also has found that an addition of powdered charcoal renders the solution limpid, and the salt resulting from it, white. The precise effect of the slight calcination, or rather aqueous fusion, in purifying the salt, is not easily determined, but as it is attended with a rapid loss of the acid, it should not be continued a moment longer than necessary.

[a] Pharm. Lond. and Edin.

A much better and more expeditious method is to employ, inſtead of common diſtilled vinegar, the ſame, concentrated by freezing.

The radical vinegar is ſtill better, but more expenſive.

This ſalt has a ſharp ſomewhat pungent taſte; it appears generally as a ſhining foliated maſs (whence its ancient name *foliated earth*) but by a ſlow evaporation it may be brought to cryſtallize even from the common ſolution,[b] and much more readily when prepared with radical vinegar. When cryſtallized it appears in thin compreſſed laminæ. It is very deliquefcent in the air, ſo that it muſt be preſerved in well cloſed bottles. It is ſoluble in nearly its own weight of water at a moderate temperature. Twice its weight of boiling alcohol diſſolves it completely when pure. It cryſtallizes without much difficulty from the hot ſaturated ſolution.

Diſtilled per ſe, it gives no acetous acid, but is chiefly reſolved into carbonated hydrogen, carbonic acid, and empyreumatic oil, along with ſome ammonia; the reſidue is carbonated potaſh. A ſolution of this ſalt long expoſed to the air, moulds, loſes its acid, and is finally reſolved into little elſe than carbonated potaſh. The uncertain quantity of water in acetous acid, makes it difficult to eſtimate the exact proportions of ingredients in this ſalt; according to Wenzel, it is in the dry ſalt as 1 of alkali to .996 of concentrated or real acetous acid. Dr. Higgins[c] found that four ounces troy (or 1920 grains) of pure ſalt of tartar, required for ſaturation 1900 grains of the ſtrong acetous acid of 1.068 ſpecific gravity (prepared on Weſtendorf's plan, by diſtilling acetited potaſh with ſulphuric acid) and by evaporation even at a heat below boiling water, and not puſhed to dryneſs, he calculates the alkali to part with no leſs than 572 grains of the acid, in becoming the cryſtallized terra foliata.

Acetite of Soda. *(Terra foliata cryſtallizata.)* The preparation of this ſalt is eaſier than the laſt. To obtain it, ſaturate diſtilled vinegar with carbonat of ſoda, and evaporate with a moderate heat. If dried rather haſtily, the ſalt is brown, but if the evaporation be ſtopped when the liquor is of a ſyrupy conſiſtence, and cooled quickly, fine long ſpicular or ſtriated bundled cryſtals are obtained, which are not deliqueſcent, but in a warm air fall to powder. According to Wenzel, the alkali is to the acid as 1 : 1.528 in the dry ſalt, and the cryſtallized contains 45.4 of water. It is ſoluble in about twice its weight of boiling alcohol.

The taſte of this ſalt is ſomewhat acrid and bitter. Diſtilled, it gives nearly the ſame products as the acetite of potaſh, only the acetous acid is not quite ſo much decompoſed.

Acetite of Ammonia. *(Spirit of Mindererus.)* This ſalt is ſeldom ſeen but in a liquid ſtate, and is uſually made by adding diſtilled vinegar to carbonated ammonia, to ſaturation. About a pint of the vinegar is required to ſaturate half an ounce of the alkali. It is difficult to procure this ſalt in a cryſtalline form, as both the ingredients are nearly equally volatile, and riſe with the watery vapour on the application of heat. However, by evaporating conſiderably this ſolution, and ſuffering it to cool in a dry cold place, ſome cryſtals may be obtained of a needled form,[d] though at the expence of a large portion of the ſalt, which is waſted by the evaporation. Hence it is more economical for this purpoſe to begin by uſing the concentrated vinegar.

Another method is by ſublimation, as obſerved by Laſſone.[e] The proceſs is the following: put in a large retort equal parts of muriated ammonia and chalk, previouſly mixed together; pour on it the ſame quantity of radical vinegar, and diſtill with a gentle heat. An aqueous liquid firſt riſes, then a copious white vapour, which preſently condenſes in the receiver, in a fine feathery or needled form. This is the cryſtallized acetite of ammonia.

The liquid ſalt is made economically, and of conſiderable ſtrength, by the following proceſs of Lowe,[f] in which a mutual decompoſition of muriated ammonia and acetited potaſh takes place. Saturate four ounces of carbonated potaſh with diſtilled vinegar, and evaporate the ſolution to the bulk of thirty-ſix ounces; add to this two ounces of muriated ammonia, and diſtill the whole in a gentle fire. The diſtilled liquid is the acetite of ammonia. It is obvious that this might readily be made more concentrated if required. The taſte of this ſalt is much like the preceding, but with ſomething peculiar.

According to Wenzel, 120 parts of concrete carbonat of ammonia require for ſaturation 229½ of radical vinegar; and eſtimating the real alkali of the ammoniacal carbonat at about 40 in 120, the proportion of real acetous acid to the alkali in this ſalt will be 240 : : 244. This ſalt is readily ſoluble in alcohol.

Acetite of Lime. Lime is entirely ſoluble in acetous acid; chalk eaſily; pure lime with difficulty. The ſolution is yellowiſh, and has a ſharp and bitteriſh taſte. By gradual evapora-

[b] Pelletier. [c] Experiments on Acetous Acid. 1786. [d] Pelletier. [e] Mem. Acad. des Sciences, 1775. [f] Gren. Syſt. Handb.

tion it leaves a ſpicular cryſtalline maſs: a ſomewhat greater heat makes it riſe up in cauliflower-like knobs. Left to ſpontaneous evaporation, it gives beautiful ſilky cryſtals, which moſt remarkably climb up the veſſel in an elegant arboreſcent plumage of cryſtals, eſpecially on the ſide expoſed to the light. This ſalt is very ſoluble both in water and alcohol. According to Wenzel, the proportion of acid to the earth is as 240 :: 145.

Acetite of Barytes. Carbonated barytes, procured in the method deſcribed under the article *Barytes*, is readily ſoluble in diſtilled vinegar. The ſolution ſlowly evaporated affords ſilken ſpicular cluſtered cryſtals. This ſalt is not deliqueſcent, has a bitteriſh taſte, diſſolves in 12 parts of cold water, and about 1¼ of boiling water, according to Buckholz.[5] This is a very uſeful ſalt as a re-agent to free radical vinegar, or any other kind, from ſulphuric and ſulphureous acid, with which as it is often prepared, it is liable to be mixed. It entirely precipitates the foreign acid, and adds no other ſpecies.

Acetite of Magnesia. Carbonated magneſia readily diſſolves in this acid. The ſolution dries to a ſweetiſh, bitter, greaſy uncryſtallizable maſs, very deliqueſcent, and readily ſoluble in alcohol. Wenzel gives the proportions of earth and acid to be as 123¼ : 120.

Acetite of Strontian. This has a ſweetiſh, and afterwards a bitter, taſte. It is ſcarcely known.

Acetite of Alumine. This earth is ſcarcely ſoluble by direct combination, except by long boiling, when by evaporation it leaves a whitiſh uncryſtallizable maſs. It is obtained by double affinity, eſpecially by the mixture of alum with acetited lead. This forms a moſt important mordant for the calico-printers, and is the only one of the earthy or alkaline acetites at all uſed in manufacture.

Acetited Metals. (For theſe ſee the reſpective metals.)

We ſhall add a few of the more uſeful double affinities ſubſiſting between the acetites and ſome of the other alkaline and earthy ſalts, where an acetite may be conveniently made by double decompoſition, as for inſtance, in forming acetited ſoda by the mixture of ſulphat of ſoda and acetite of lime. We ſhall only give thoſe in which the newly formed acetite remains in ſolution, and the other compound is moſtly precipitated, either on mixture or at leaſt after moderate evaporation.

Acetited Potaſh is decompoſed by the ſulphat of magneſia, and by alum.

Acetited Lime is decompoſed by the ſulphats of potaſh, ſoda, ammonia, and magneſia, by alum, and by all the alkaline and earthy phoſphats.

Acetited Barytes is decompoſed by all the ſulphats.

Acetited Lead is decompoſed by all the alkaline and earthy ſulphats, and by the muriats.

For the other affinities of the acetites ſee the Appendix.

ACID. *Saure*, G.

All thoſe ſubſtances which impreſs the organs of taſte with a ſharp, ſour, and cooling ſenſation, are in common language denominated Acid. Both Nature and Art preſent us with many of theſe bodies, a few of which poſſeſs this character in ſo faint a degree as to be ſcarcely perceptible, while others are ſo ſtrongly corroſive, as to require large dilution with water, before they can be ſafely applied to the living animal organs. From the power which acids have of combining with and diſſolving almoſt all bodies, they are of firſt-rate importance and very extenſive application to the various proceſſes carried on in the laboratory: hence they very early engaged the attention of chemiſts, and have to the preſent time been the ſubjects of more experiments than perhaps any other ſubſtances.

Acids, according to the corpuſcular theory, which explained all chemical phenomena by the mechanical action of the ultimate particles of bodies, were conſidered as a genus of ſalts compoſed of minute and ſharp ſpiculæ, which readily penetrated into the minute pores of the ſubſtances expoſed to their action, and thus ſeparated their component parts from each other, while at the ſame time the acid became neutralized by having its points ſheathed in the pores of the body with which it was mixed. The weakneſs however of this theory was demonſtrated by Boyle, and by Stahl, in his work on ſalts; and the ſolvent power of acids was reduced by Macquer and his contemporaries to the general laws of chemical affinity.

A ſtriking fault of the ancient chemiſts was their diſpoſition to ſyſtematize and draw general concluſions from a few and incorrect experiments: hence they ſuppoſed that all combuſtible bodies were indebted for their common properties to the preſence of a combuſtible element, called by them phlogiſton or ſulphur. In all the ſpecies of metals they recognized a common metallic principle, under the name of mercurial earth; ſo alſo they imagined that

[5] Syſt. Handbh.

there exiſted an univerſal ſaline element or principle of acidity common to all acids. Beccher affirmed this acid principle to be compoſed of water and earth, and therefore not entitled to rank as an element. Stahl was induced to believe that the ſulphuric acid was the original one, of which all the reſt were only modifications. A ſimilar opinion was held by Sage and Landriani, except that the former ſuppoſed the phoſphoric, and the latter the carbonic, to be the elementary acid. The diſcovery of oxygen gas in 1774, by Dr. Prieſtley, offered a new and moſt important ſubſtance to chemical inveſtigation, which at length led to an entire change in the theory of the formation of acids. The illuſtrious Lavoiſier, in 1778, preſented to the Royal Academy of Sciences at Paris, a memoir on the acid of ſugar, in which, after deſcribing the method of preparing this acid from ſugar and nitric acid, he concludes that the converſion of the nitric acid into nitrous gas, is occaſioned by the loſs of a portion of oxygen, abſtracted from it by the ſuperior affinity of the ſugar, which laſt, in conſequence of its combination with oxygen, acquires the characters of an acid. The ſame able chemiſt diſcovered ſoon after, that phoſphorus, ſulphur, and charcoal, when inflamed in oxygen gas, combine with the baſe of this air, acquire an additional weight, equal to that of the gas which diſappears, and are ſeverally converted into the phoſphoric, ſulphuric, and carbonic acids. Induced by theſe facts, he proceeded to generalize the inferences drawn from them, and maintained that the baſe of oxygen gas was the univerſal acidifying principle, which by combining with ſimple or compound combuſtibles, produced the various ſpecies of acids. This explanation has been generally acquieſced in, though ſome objections to it have lately been brought forward, founded upon the analyſis of the Pruſſic acid, which appears to conſiſt ſolely of hydrogen, carbon, and azot. The claim however of this ſubſtance to the character of an acid is very equivocal, as it neither taſtes ſour, nor alters vegetable colours. With equal or even ſuperior propriety might ſulphuretted hydrogen be placed in the liſt, as indeed it has lately been done by ſome German chemiſts, under the name of the hydrothionic acid.

Although every combuſtible body is capable of uniting with oxygen, it is not neceſſarily an acidifiable baſe; nor does this appear at all to depend on the inability of the baſe to combine with a ſufficiently large proportion of oxygen, for hydrogen when ſaturated with a larger proportion of oxygen than is required for any acid, produces only water. The developement of an acid is by no means to be conſidered as an evidence of the compleat ſaturation of its baſe with oxygen, there being ſeveral acids capable of combining with additional quantities of this principle, and thence acquiring new and more decided acid characters. It is even ſuppoſed that ſome baſes may be acidified in three ſeveral degrees, preſerving in each diſtinct ſpecific characters; hence reſults an important arrangement of theſe bodies as they are acidified in the firſt, ſecond, or third degree. The reformed chemical nomenclature has ingeniouſly diſtinguiſhed theſe ſtates by the terminations *ous*, and *ic*, and the prefix *oxy* (for oxygenated). Thus ſulphur at the loweſt ſtate of oxygenation at which it acquires acid properties, is called *ſulphureous* acid; when ſtill further oxygenated, it becomes *ſulphuric* acid: thus alſo muriatic acid, when raiſed to its higheſt ſtate of oxygenation, takes the name of *oxymuriatic* acid.

The characteriſtic properties of acids are the following:

1. When taken into the mouth they occaſion a ſour taſte.

2. They change certain vegetable blue colours to red, ſuch as tincture of litmus, or ſyrup of violets; and reſtore the blue colours which have been turned green, or the red colours which have been turned blue, by an alkali.

3. They have a ſtronger affinity for alkalies than theſe have for any other ſubſtance.

4. They unite with earths, with alkalies, and metallic oxyds, forming the numerous and very important claſſes of neutral, earthy, and metallic ſalts.

The old chemiſts divided acids into mineral, vegetable, and animal, according to their ſuppoſed origin; this however is not only an inconvenient, but an an incorrect method of arrangement, as many of theſe bodies are found in all the three natural kingdoms. Perhaps the following is as good a way as any other of exhibiting their names and compoſition.

I. Acids with ſimple radicals.

Sulphur . . .	1. Sulphureous 2. Sulphuric
Azote	3. Nitrous 4. Nitric
Phoſphorus . .	5. Phoſphoreous 6. Phoſphoric
Carbon	7. Carbonic
Molybdena . .	8. Molybdic

Tungſten . . . 9. Tunſtic
Chrome . . . 10. Chromic
Arſenic . . . 11. Arſenious
12. Arſénic

II. Acids with double radicals.

Carbon and Hydrogen
13. Acetous
14. Acetic
15. Tartareous
16. Citric
17. Oxalic
18. Malic
19. Gallic
20. Benzoic
21. Succinic
22. Lactic
23. Mucous or Saccholactic
24. Camphoric
25. Suberic

III. Acids with triple radicals.

Carbon, Azot, and Hydrogen.
26. Sebacic ?
27. Zoonic
28. Uric or Lithic

IV. Acids with unknown radicals.

29. Muriatic
30. Oxy-muriatic
31. Fluoric
32. Boracic

V. Compound Acids.

33. Nitro-muriatic (Nitric & Muriatic)
34. Pyro-mucous } Acetic & Empyreumatic Oil.
35. P— tartareous } Acetic & Empyreumatic Oil.
36. P— ligneous } Acetic & Empyreumatic Oil.
37. Formic (Malic & Acetic

VI. Dubious acids.

38. Laccic
39. Bombic

VII. Acids deſtitute of Oxygen.

40. Pruſſic (Hydrogen, Carbon, and Azot)
41. Hydrothionic (Sulphur & Hydrogen)

ACID-HOLDER. An article of chemical apparatus, ſee Appendix, No. 1. at the end of Vol. ii.

ACIDIFIABLE BASE.

An acidifiable baſe is any ſubſtance, whether ſimple or compound, that is capable of uniting without decompoſition with ſuch a quantity of oxygen as thereby to acquire acid properties. The term itſelf was unknown in chemiſtry previouſly to the diſcoveries of Lavoiſier on the compoſition of acids; becauſe thoſe bodies that are now proved to be convertible into acids, by combination with oxygen, were ſupported by Stahl, and his followers, to be already acids united with phlogiſton. Thus ſulphur, which according to the preſent theory is a chemical element, and capable, by combination with oxygen, of being converted into ſulphuric acid, was by the Stahlians conſidered as a compound of ſulphuric acid and phlogiſton.

ACIDULOUS.

This term is emplóyed to expreſs in general a ſlight degree of acidity, or an exceſs of acid in a compound ſalt: hence ſulphat of potaſh, with exceſs of acid, is called *acidulous* ſulphat of potaſh, or ſuper-ſulphat of potaſh. The reverſe of this quality, or an exceſs of alkali in the compoſition of neutral ſalts, is uſually denoted by the prefix *ſub.* as *ſub-borat of Soda* (common Borax).

ACIDULUM. *Acidule.* Fr.

This is a name which is given in the new nomenclature to a genus of native vegetable ſalts, conſiſting of potaſh ſuperſaturated with an acid. We are at preſent acquainted with two ſpecies, the tartareous acidulum, or *acidulous TARTRITE of potaſh*, and the oxalic acidulum or *acidulous OXALAT of potaſh*.

ACRID MATTER OF PLANTS.

The peculiar biting acrid taſte poſſeſſed by ſeveral of the vegetable tribe, has been ſuppoſed, though with little probability, to be a diſtinct principle, in general eluding chemical reſearch; and not a mere quality of certain known parts, ſuch as eſſential oil.

The acrid matter may be extracted in moſt inſtances by water, or weak acids, or alcohol. It forms the baſis of ſeveral preparations in pharmacy. The vinegar of ſquills is an example.

As an object for the chemiſt it ſtands in the ſame ſituation as the AROMA, and its ſeparate exiſtence is equally dubious.

ACTINOLITE. See STRAHLSTEIN.

ADAMANTINE SPAR. See CORUNDUM.

ADHESION. This curious ſubject belongs rather more to another branch of natural philoſophy than to chemiſtry. As far however as it is connected with the latter, it will be noticed under the article AFFINITY.

ADIPOCIRE.

The name given by M. Fourcroy to a peculiar ſpermaceti-like ſubſtance, procurable from a certain unctuous maſs, into which moſt of the ſoft parts of animal bodies are converted by ſpontaneous change, under certain circumſtances of temperature and moiſture, and more eſpecially

when protected from the free access of atmospherical air.

Chemistry is indebted principally to the industry and talents of M. Fourcroy, for what is known concerning this singular substance, so that its chemical history is of recent date, and it makes such an important addition to our knowledge in what has hitherto been the most defective part of chemistry, that of animal matter, that we shall examine it with some minuteness.

The history of the discovery of this substance lies within a small compass.—A very large burying-ground, belonging to the church des Innocens, at Paris, had for many centuries been the receptacle of a considerable part of the population of that metropolis.[a] The method of depositing the bodies had long been to dig large pits from twenty-five to thirty feet deep, capable of containing from twelve to fifteen hundred bodies, which, when filled, were covered with a few feet of earth, and suffered to remain undisturbed for a longer or shorter time, that is from fifteen to thirty years, according as room was wanted. The average number of burials had been for many years about three thousand annually, so that the soil for many feet beneath an area of seven thousand square yards, was almost an entire mass of animal matter, which had gradually risen several feet above the natural level of the neighbouring ground. For nearly two centuries complaints had been made of the insalubrity of such an immense mass of putrefaction, within the heart of a large closely-built populous city, and at last, in the year 1782, the government undertook the formidable operation of removing the greater part of the soil, with all its contents. This business necessarily exposed to view the situation of these common burying-pits, in every different period of spontaneous change, and the observations of several able scientific men, assisted by the experience long acquired by the grave-diggers, enabled them to collect the following very interesting particulars.

In the first of these pits which was examined, and which had been filled up about fifteen years, the bodies were found sunken to the bottom of the coffins, as if they had been pressed down with a weight; on removing what remained of the linen shroud, the body beneath it was found converted into irregular masses of a soft unctuous cheese-like substance, grey brown in colour, breaking down under the fingers like spermaceti. The smell of the bodies thus changed was not very offensive, so that they could be handled without much repugnance. On further examination, it was found that every part of the body, except the bones, nails, and hair, was converted, sooner or later, into this spermaceti-like substance; and by the evidence of the grave-diggers it appeared that this change was completed in these large receptacles in about three years, and that it was more perfect in the center of the pits than in the upper extremities, where the bodies were nearer the surface, and therefore more exposed to the action of the sun and air.[b] Several varieties of texture and appearance of this substance were noted, sometimes quite dry and brittle, with a polished surface and a metallic lustre, at other times waxy, or soft as curd.

We shall not dwell further on the contents of this very interesting memoir, in which every particular that could be collected on so novel a subject, is detailed with great accuracy and apparent fidelity; we shall proceed to the chemical analysis of this substance.[c]

Exposed to a heat not greater than boiling water, it melted, and by very slow distillation continued for many days, and regulated so as to produce as little decomposition as possible by the mere heat, it gave about one-sixteenth of its weight of a very fetid water, holding a quantity of ammonia in solution. The remaining mass was rendered somewhat more brittle by this process.

A long exposure to the air produced a similar effect in dissipating much of the alkali, and bringing the residue to a nearer resemblance to wax.

Its habitude with water shewed its saponaceous nature in a very striking manner. When rubbed in a mortar with a little cold distilled water, it readily and uniformly mixed with it, into a whitish emulsion, which, on adding more liquid, resembled exactly a solution of soap in water, frothed in the same manner by agitation, and was, like soap, curdled and decomposed by hard well water, by acids, by lime water, and by metallic salts. On filtering the solution, which took place very slowly, the clear liquor remained excessively fetid, and on long standing, left by evaporation ammoniacal phosphate.

Mixed with lime and a little water, a strong odour of ammonia was given out, together with a very fetid gas, and after heating and lixiviating, the residue was a mixture of the lime with the oily base of the subject of experiment, from which the lime was afterwards separable by muriatic acid, leaving a dry, combustible, unc-

[a] Thouret, J. Phys. tom. 38. [b] Fourcroy An. Chim. tom. 5. [c] Fourcroy An. Chim. tom. 8.

tuous, brittle, cryſtallizable, waxy matter, ſhining in its fracture, and now entirely inſoluble in water.

The fixed alkalies operated like lime in diſplacing the ammonia, and formed with the unctuous reſidue a true ſoap.

Liquid ammonia added to it, and gently warmed, immediately diſſolved it into a clear limpid fluid, afterwards a little opaleſcent when cooled.

The acids ſhewed a very powerful action on this ſubſtance. Concentrated ſulphuric acid added to it yielded a gas, which M. Fourcroy deſcribes as more repulſively fetid than any which he had ever experienced. The dilute acid acted with leſs vehemence, and uniting with the ammonia, and alſo with ſome lime which the fatty ſubſtance contained, formed the ſulphats of ammonia and lime, and ſeparated the ſame peculiar concrete oil which has been above deſcribed.

Nitrous acid acted in a ſimilar manner, but with more energy. When the ſubſtance was pure no azotic gas was given out, but much carbonic acid. The concrete oil ſeparated as before.

Highly rectified alcohol had no effect upon it when cold, but when heated to boiling it readily combined with a third of its weight into a brown tranſparent liquid, which on cooling again depoſited in feathery flakes about ſeven-eighths of what it had diſſolved. The remainder was recovered by evaporation, and appeared to be the purer concrete oil, unmixed with ammonia, the only part therefore ſoluble in cold alcohol.

From the above ſhort abſtract of a very full and maſterly analyſis, it will appear that the fatty matter to which animal bodies are converted by long inhumation in deep moiſt ſoil, is for the moſt part a very peculiar ſaponaceous compound, formed of a certain quantity of ammonia, united with a ſingular kind of concrete ſuet-like wax, hitherto undeſcribed, and to which M. Fourcroy has given the very appropriate name of *Adipocire*. The compound beſides contains ſome phoſphoric and other ſalts, of little import to the preſent ſubject.

This Adipocire, itſelf inſoluble in water, is rendered miſcible with it by its ammonia, or by the addition of any other alkali. It is ſeparated from its neutral combinations by the dilute mineral acids, and partly by alcohol, and even in ſome degree by ſimple expoſure to air. In its natural ſtate it is however ſo thoroughly and intimately blended with water, that it conſtantly loſes weight by deſiccation, and it is ſcarcely poſſible to determine when it has parted with the laſt portions of this fluid. Its colour is always browniſh or yellowiſh, and though when much divided it appears white, it reſumes in maſs, part at leaſt of its original colour. When perfectly dry it has a ſingular flexible but granular texture, almoſt cryſtalline, but with ſome varieties, ſo that ſometimes it more reſembles wax, ſometimes ſpermaceti.

It is not merely however by inhumation that animal matter is thus changed. Immerſion into cold water for ſome weeks will produce the ſame alteration, and with much more rapidity. Since the notice of chemiſts has been directed to the ſubject, various obſervations have been made of human bodies or other animals, which by accident have remained many days in cold running water, which have afforded a ſimilar matter. The ſame is often to be obſerved in large diſſecting rooms, where putrid fleſh accidentally remains neglected in a quantity of cold water, and the experiment has been alſo tried with ſucceſs by Dr. Gibbes.[c] He ſtaked part of the carcaſe of a cow to the bottom of a running ſtream, and in ſome months the greater part of it was changed into adipocirous matter In making it in this manner, however, much of it is loſt, being carried away by the water, which is conſtantly covered with a fatty pellicle for ſome diſtance, while the proceſs is going on. The ſame chemiſt, in endeavouring to purify it for experiment in the large way, found that the fetid ſmell remained after ſimple melting and ſtraining, but on the affuſion of nitric or oxymuriatic acid, it entirely diſappeared, and became by the latter nearly as white as bleached wax.

Another method of procuring ſmall quantities of Adipocire, in a ſtate very nearly reſembling that produced by putrefaction, is to ſteep the lean of meat in a moderately dilute nitrous acid.[d] In three days the texture is changed, it becomes white, waxy, and when taken out, gently melted and well waſhed, it exhibits moſt of the characters of adipocire. The nitric acid however appears to adhere to it with great obſtinacy.

The reſemblance between adipocire and ſpermaceti is ſo ſtriking, that ſome characteriſtic differences are requiſite to diſtinguiſh the two ſubſtances. Spermaceti and the pureſt adipocire obtained from the putrefaction of buried human bodies,[e] are both ſmooth and unctuous to the touch, lamellar and brilliant

[c] Phil. Tranſ. vol. 84. [d] Gibbes. Phil. Tranſ. vol. 85. [e] Fourcroy.

in fracture, not ductile, but easily crushed between the fingers. Heated, the spermaceti melts at about 133°, the other at 126.° and after cooling, becomes more brittle. When very pure, the adipocire has no odour, that of spermaceti is faint but distinguishable. Both are soluble in hot alcohol, but in very different proportions, the adipocire requiring no more than two-thirds of its weight of this liquid, and the spermaceti sixteen times its weight. Both are separable from it by cooling, with some little differences of appearance. Liquid ammonia also, when cold, dissolves only the adipocire, and even when heated it scarcely has any action on spermaceti.

Other experiments make some slight differences in the congealing temperature of these substances. Dr. Bostock,[f] found the adipocire made by nitric acid to congeal at 90°, Dr. Gibbes at 112°. Boiling ether dissolves about one quarter of its weight, which mostly separates on cooling.

The resemblance which adipocire bears to spermaceti, has suggested the idea of converting to some economical use the offal carcases of horses, and other animals which are not the food of man. The first process of making adipocire by immersion in water, is spontaneous, but the subsequent purification would probably demand much attention. It remains as a probable source of profit to the manufacturing chemist, and to the philosophic, a promising vein for future discovery.

ADOPTER. An article of chemical apparatus. (See the Appendix).

ADULARIA. See Felspar.

ÆDELITE. See Zeolite.

AERIAL ACID. The term given by Bergman to Carbonic Acid *Gas*.

AES VENERIS, AES USTUM. Names formerly given to a preparation of copper and sulphur strongly calcined. It has only been known in medicine, and is now disused.

AETHIOPS, *Antimonial*. A pharmaceutical preparation, made by uniting the crude or black sulphuret of antimony with running mercury, till the latter is totally extinguished. It is therefore a mixture of the sulphurets of antimony and mercury.

AETHIOPS, *Martial*, or Lemery's *Saffron of Mars*, is iron filings so far rusted by water, as to be pulverizable, but still magnetical. It is employed in medicine. As a chemical preparation, see Iron.

AETHIOPS, *Mercurial*. A term given by some chemists to mercury rubbed down, or *extinguished* by trituration with gum-arabic. It is only used in medicine.

AETHIOPS, *Mineral*. The black sulphuret of Mercury, made by triturating equal parts of mercury and sulphur, and used in medicine.

AFFINITY. *Affinité*, F. *Verwandschaft*, G.

All the phenomena of nature may be ultimately referred to two kinds of motion, attraction and repulsion. Attraction may again be subdivided into that which takes place between bodies at sensible distances, including gravitation, magnetism, and electricity; and that which acts only at insensible distances, such as cohesion and chemical affinity.

Cohesion, or homogeneous affinity, is the attraction between the component particles of homogeneous bodies, as between two globules of quicksilver: when made to touch each other, they run together into one globule, and are mixed in the most intimate manner, without however undergoing any alteration in their chemical or physical properties.

Chemical or heterogeneous affinity can only take place between dissimilar particles; and the change of properties which is the consequence of this combination, cannot in the present imperfect state of our knowledge be inferred from those of the elementary particles. As when quicksilver is added to melted sulphur, the result is a compound possessed of neither the colour, the splendour, the inflammability, the volatility, nor specific gravity of either of its constituent parts.

These two affinities are the great agents in all the operations of nature and art, which are referable to the science of Chemistry; not only as instruments of Synthesis, as might be supposed from the primary meaning of the term, but also as the sole means of analysis, there being no way of resolving a chemical compound but by exposing its elements to the action of stronger affinities than those which retain them in union.

The force of homogeneous affinity is peculiar for all the substances in nature; thus there is a striking difference between the cohesion of equal masses of iron, tin, and glass; and the cohesion even of the same individual particles varies remarkably, according to the quantity of heat with which they are either mixed or combined, as for example, in the particles of water in the state of ice, of water, or of steam.

The force of heterogeneous affinity is also peculiar; for out of the whole series of bodies which are capable of uniting with any given

[f] Phil. Journal, Vol. 4.

body, there are no two whoſe force of affinity appears to be equal. This may in part depend on the reſpective differences of their cohefive attraction, but is no doubt principally owing to a real difference in the energy of their chemical affinity. Moſt ſubſtances exiſt in viſible maſſes, and therefore under the influence of cohefion; but as chemical affinity takes place between heterogeneous *elementary particles*, it is obvious that theſe two attractions are always in oppoſition to each other; hence there is a priori a poſſibility, which is alſo confirmed by experiment, that the particles of one body may have an affinity for thoſe of another, and yet on account of the ſuperior cohefion of the two ſubſtances, the chemical attraction may be imperceptible. It is impoſſible therefore to aſcertain whether every ſpecies of particles has a chemical affinity for all the other ſpecies, although it is for the moſt part the opinion of the beſt chemiſts that this is really the caſe.

Heterogeneous affinity may be conveniently divided into *ſimple*, where only two ſimple ſubſtances are concerned; *ſingle elective*, where only three are concerned; and *compound*, where a greater number is brought into action.

Before, however, we proceed to enumerate the characteriſtic circumſtances of each, it will be neceſſary to explain what is here meant by a *ſimple* ſubſtance. The ancients believed many bodies to be ſimple which the ſuperior ſkill and knowledge of modern chemiſts have moſt aſſuredly decompoſed; and there is no reaſon to believe that in any one caſe has chemical analyſis been able to procure the real elements or ſimple conſtituent parts of ſubſtances. A chemical element, therefore, does not ſo much ſignify a body that is abſolutely undecompoſable, as one that has not yet been reſolved. But there is another ſenſe in which even bodies that are known to be compound may be conſidered as ſimple, and that is where they combine with other ſubſtances, without being themſelves decompoſed. Thus ſulphuric acid, which conſiſts of oxygen and ſulphur, becauſe it unites with earths, alkalies, and metallic oxyds, without being decompoſed, may in theſe caſes be conſidered as acting the part of a ſimple ſubſtance, and would no doubt have been ſo eſteemed, if all our knowledge of this acid was confined to the phenomena which it exhibits when acting on the above mentioned ſubſtances. In this ſenſe alone we uſe the term when ſpeaking of chemical affinity.

Simple affinity takes place when only two ſpecies of particles, either really ſimple or at leaſt acting as ſuch, are brought in contact with each other. In this caſe there are obviouſly two contending forces, that of cohefion tending to retain each ſpecies of particles in diſtinct maſſes, and that of compoſition or chemical affinity tending to blend, and intimately unite each particle of one ſpecies with one of the other. If both ſubſtances are ſolid, there will be no combination, whatever may be the ſtrength of their mutual affinity, for the contact in this inſtance can only be ſuperficial, and even this very imperfectly. Thus iron and ſulphur, which in favourable circumſtances will unite with great energy, are wholly incapable of action if each is in a ſolid form. Now the ſolidity or cohefion of a body may be reduced in two ways, either imperfectly, by mechanical means, ſuch as pounding, cutting, filing, &c. or more completely by the application of heat, it being the uniform effect of this agent to enlarge the bulk and weaken the cohefion of all bodies that are expoſed to its action. It is from long experience of the effects of cohefion in preventing chemical union, that the axiom has originated, that "bodies do not act on each other except they are liquid;" which, although like many of the old chemical maxims, it is not to be received without certain modifications, is yet, in many caſes, ſtrictly true: the efficacy of affinity being *ceteris paribus* inverſely as the attraction of cohefion, and the fluidity of one at leaſt of the ſubſtances, is in all caſes neceſſary to chemical compoſition. An example of ſimple affinity is when quickſilver and melted ſulphur are blended together. Here, the cohefion of the ſulphur being weakened by fuſion, and the quickſilver being alſo fluid, the quieſcent force or attraction of cohefion, is unequal to the reciprocal affinity between the ſulphur and the metal, which in conſequence becomes efficacious, and combines the two into one body. All the caſes of ſolution in which no decompoſion of the menſtruum or the ſolvent takes place, are examples alſo of ſimple affinity. Thus when common ſalt is thrown into water, the chemical affinity of the two being ſtronger than their reſpective cohefive attractions, a compound is produced in which the particles of ſalt water are no longer diſtinguiſhable by the eye, nor ſeparable from each other by any mechanical force.

While a lump of ſalt is diſſolving in water, it is obvious that the particles thus taken up will be conſtantly approaching towards an equality with thoſe of the water, ſo that the maſs of ſalt, every ſquare inch of whoſe ſurface

was at firſt in contact with an equal area of water, is at length ſurrounded with a fluid of which the ſalt that it holds in ſolution forms a very notable proportion: therefore the particles of water in contact with any given ſurface of the undiſſolved ſalt, will be continually diminiſhing in number, and leſs able to overcome the coheſion of the ſalt; hence a period will arrive in which the coheſion of the undiſſolved ſalt, and the affinity of the remaining unſaturated particles of water, will exactly balance each other, and no further action will take place.

That ſolution is an inſtance of chemical agency, and not merely the diffuſion of the particles of a ſolid through a fluid, is evident alſo from this, that water will diſſolve very different proportions of different ſalts, which can only ariſe from the varieties in the force of its affinity; in certain circumſtances alſo it will protect the ſubſtances that it holds in ſolution from the action of others, by means of its ſuperior affinity for them.

It has been too much the cuſtom in reaſoning upon the more complicated caſes of affinity, to overlook entirely that by which water or any other menſtruum retains in ſolution the various objects of chemical experiment, and to conſider a ſolution of ſalt for example, as the ſame thing with pure ſalt, only in a more convenient form, and hence have ariſen many anomalies and errors.

Hitherto we have only conſidered the effects that take place when a ſingle chemical affinity is concerned; we have now to treat of thoſe caſes in which there are two chemical affinities acting in oppoſition to each other. Common nitre is compoſed of nitric acid and potaſh; if to a ſolution of this neutral ſalt in water, we add a quantity of ſulphuric acid equal to the nitric acid of the nitre; the ſulphuric acid being incapable of combining with this ſalt, and having a ſtrong affinity for the potaſh, its alkaline baſe, a decompoſition of the nitre, is effected, and the alkali is divided between the two acids in the exact ratio of the ſtrength of their reſpective affinities. The water then, inſtead of containing nitre and ſulphuric acid, will hold ſulphat of potaſh, with a ſmall exceſs of ſulphuric acid and nitrat of potaſh, with a large exceſs of nitric acid; but as the new compounds have at leaſt as ſtrong an affinity for water (or are equally ſoluble) as the ſulphuric acid and nitre from which they are formed, they ſtill remain intimately mixed with each other, and are incapable of being ſeparated by mere mechanical means. The affinity of the ſulphuric acid for potaſh is greater than that of the nitric acid, and therefore in the experiment juſt recited, the ſulphat of potaſh produced is greater than the quantity of nitre remaining undecompoſed, ſince equal parts of each acid are ſuppoſed to be preſent. But the efficacy of affinity depends not only on the abſolute force, but on the relative maſſes of the ſubſtances employed; we may therefore compenſate in many caſes the weakneſs of the affinity by a proportionate exceſs in quantity: thus although ſulphuric acid has a ſtronger affinity for potaſh than nitric acid has, yet ſulphat of potaſh, when treated with a large exceſs of nitric acid, is in great part decompoſed, and may be made to depoſit cryſtals of nitre. Hence it follows that the force with which any compound reſiſts decompoſition, is in the inverſe ratio of the mutual ſaturation of its two elements; and that no compound how weakly ſoever its elements may be combined, can be wholly decompoſed by the addition of any third ſubſtance, however powerful may be its affinity for either of the other two.

Till the late experiments of Berthollet on this ſubject, all chemiſts ſeem to have coincided with Bergman, who maintained that in caſes where a compound was decompoſed by the ſuperior affinity of one of its elements for a third ſubſtance, there was a *total* transfer of the baſe from the ſubſtance of the weakeſt to that of the ſtrongeſt affinity; and hence originated the term *ſingle elective affinity*, which was made uſe of to ſignify that if to the compound A. B. a body C. was added, poſſeſſed of a ſuperior attraction for A. than B. has, A. would by election or choice as it were, quit B. entirely, and form with C. a new compound A. C. to the excluſion of B.

In the example already given of the action of ſulphuric acid on nitre, we have ſhewn that, though a decompoſition is effected, there is no ſpontaneous ſeparation of the different ſubſtances, on account of their ready ſolubility in the common menſtruum; but in a great number of the caſes of ſingle elective affinity, one, and ſometimes both the ſubſtances which are the reſult of the experiment, are ſo little ſoluble, that they ſeparate ſpontaneouſly either wholly or in part, from the menſtruum; or, in chemical language, are *precipitated*: and it is only by taking advantage of this ſuperiority of the affinity of coheſion over that of compoſition, that we are able to procure in a ſeparate ſtate the elements of any compound.

Thus if to a ſolution of ſulphat of potaſh in water, we add barytes, alſo diſſolved in water, a partition will be made of the ſulphuric acid, between the barytes and potaſh; in conſequence ſulphat of barytes will be produced, and ſulphat of potaſh, with exceſs of alkali: but the former of theſe ſalts being hardly at all ſoluble either in water or in alkaline ſulphat of potaſh, will fall to the bottom, and the fluid will hold only the latter ſalt in ſolution. A freſh addition of barytic water will occaſion a further precipitation of ſulphat of barytes, till at length the liquor will come to be a ſolution of potaſh, with an imperceptible proportion of ſulphuric acid and ſulphat of barytes. Sometimes the whole contents of the fluid are precipitated, as when barytes is added to ſulphat of zinc. Here the effect of the barytes is to divide the ſulphuric acid, which was before combined wholly with oxyd of zinc, between the metal and earth, according to their reſpective affinities; and as ſulphat of barytes and oxyd of zinc, with a little ſulphuric acid, are inſoluble in water, or in ſulphat of zinc, both ſubſtances are precipitated, leaving only the undecompoſed metallic ſulphat in ſolution, which by a further addition of barytes, may be again decompoſed and precipitated, till no greater quantity of ſulphat of zinc is left than would form with barytes $\frac{1}{40000}$ of the whole maſs, becauſe ſulphat of barytes in this proportion is ſoluble in water: or in other words, the chemical affinity of water for ſulphat of barytes, is to the affinity of coheſion between the particles of this ſalt, as 1 to ſomewhat leſs than 40000.

Compound affinity differs from ſingle elective affinity in being more complicated. In the former a body is decompoſed by the ſuperior affinity of one of its elements for a third ſimple ſubſtance; in the latter a ſimilar effect is produced by the addition of a compound body which is itſelf decompoſed in the proceſs. There are many advantages which this method of operating has over that by ſingle elective affinity, and particularly that decompoſitions are much more complete, and require a ſmaller proportion of ſubſtances to be added in order to effect the propoſed changes. Thus if ſulphat of potaſh is to be decompoſed by nitric acid, in order to procure cryſtals of nitre; if we merely add theſe two ſubſtances together, the affinity of ſulphuric acid for pot-aſh being greater than that of nitric acid, a large exceſs of this latter will be required, and after all only a very partial decompoſition can be effected. We ſhall gain our end much more completely by previouſly combining the nitric acid with ſome ſubſtance that has as ſtrong an affinity (or even ſtronger) for ſulphuric acid, as nitric acid has for potaſh. If, for example, we make uſe of nitrat of barytes for this purpoſe, we ſhall attack the ſulphat of potaſh, not only by the affinity of nitric acid for its alkaline baſe, but by that of barytes for its acid, and the concurrent action of theſe two powers will accompliſh what neither ſeparately could effect ſo entirely or by ſuch ſmall quantities. In the caſe here ſuppoſed, the ſulphuric acid of the ſulphat of potaſh, and the barytes of the nitrat of barytes, will combine with each other, and form ſulphat of barytes, which will precipitate, while the nitric acid and potaſh being now at liberty, will combine eagerly with each other and form nitre. Hitherto we have only conſidered the *divellent* attractions, or thoſe which tend to break the former combinations and produce new ones; it is equally neceſſary however to notice thoſe which are called *quieſcent* affinities, from their tendency to maintain the former combinations, and in conſequence oppoſe all further change. Thus while the nitric acid and barytes are attracted towards the potaſh and ſulphuric acid, this motion is oppoſed by the affinity that ſubſiſts between the nitric acid and barytes, and the potaſh and ſulphuric acid, and it is only in conſequence of the exceſs of the divellent over the quieſcent affinities that any change takes place. Hence it is that there is no ſuch reciprocal action in caſes of compound affinity, as takes place in thoſe of ſingle elective affinity. Nitrat of barytes may be more or leſs completely decompoſed, by the proper quantities either of potaſh or of ſulphuric acid, as may ſulphat of potaſh by nitric acid or barytes; or nitrat of potaſh by ſulphuric acid, or barytes, or ſulphat of barytes by nitric acid or potaſh. But nitrat of barytes being decompoſable by ſulphat of potaſh, no exceſs whatever of nitrat of potaſh can decompoſe in the ſmalleſt degree ſulphat of barytes, becauſe the quieſcent forces are ſuperior to the divellent ones, and muſt always bear the ſame ratio to each other, whatever be the proportions of the two compound ſubſtances.

The ſubject of chemical affinity has engaged the attention of the moſt able chemiſts from Bergman to Berthollet. Before the treatiſe of the latter philoſopher, the opinion of Bergman had been univerſally adopted concerning the total change of baſe in all caſes of decompoſition; and many general laws and inferences

baſed upon this fundamental error were eſtabliſhed, which the ſuperior accuracy of Berthollet has ſhewn to be utterly groundleſs. The deſtruction of former errors, and a general view of the difficulties of the ſubject, and the proper method of experimenting, together with the enunciation of a few facts, which ſeem of very extenſive application, compriſe nearly the whole of the labours of Berthollet on this ſubject: it is therefore at preſent in an extremely imperfect ſtate.

In the Appendix will be given Bergman's table of ſingle elective affinities, together with the ſchemes of compound affinity, and Mr. Kirwan's table of the numerical ſtrength of affinities; where alſo may be found ſome remarks on the authority to which they appear reſpectively to be entitled.

AGALMATOLITE. See BILDSTEIN.

AGARIC MINERAL. See BERGMILCH.

AGATE. See KALZEDON.

AGGREGATE, AGGREGATION.

Theſe terms are at preſent but little uſed. Some chemiſts have employed the phraſe Affinity of Aggregation, to expreſs that force by which bodies remain in maſs, and therefore without change, in oppoſition to the phraſe Affinity of Compoſition, which is the ſame as chemical affinity. Hence they have diſtinguiſhed two kinds of aggregation, homogeneous or coheſion, being the attraction that takes place between ſimilar particles; and heterogeneous or adheſion, being the attraction between the external ſurfaces of maſſes. An aggregate therefore means a maſs in general.

AGUSTINE.

By this term, barbarouſly compounded of Greek and Latin, and meaning, *without taſte, inſipid*, Profeſſor Trommſdorf has diſtinguiſhed a ſuppoſed new earth, diſcovered by him in the year 1800.

The mines of Johan Georgenſtadt contain a mineral reſembling the berill, which being analyſed, yielded unexpectedly, a new earth, called by its inventor Aguſtine, from its forming inſipid ſalts with acids.

This earth, when pure, has a great reſemblance to alumine; combines very feebly with carbonic acid; hardens by expoſure to fire, and is inſoluble in water. It differs however from pure clay in the following particulars. It is inſoluble in any of the three alkalies, whether cauſtic or carbonated, in the moiſt or dry way. It combines with acids forming nearly inſipid ſalts. It is equally ſoluble after induration by fire as before. With ſulphuric acid it forms a ſalt of difficult ſolution, and perfectly inſipid, but which by a ſlight exceſs of acid becomes ſoluble, and cryſtallizes in ſtars. Its acidulous phoſphat is alſo very ſoluble; but its acetite is ſcarcely at all ſo.

Theſe are all the facts as yet known concerning this ſubſtance, and they reſt upon the ſole uncorroborated teſtimony of Profeſſor Trommsdorf.[a]

AIGUEMARINE. See BERILL.

AIR. In that part of chemical enquiry which relates to the conſtitution of gaſeous bodies, ſome of the phyſical properties of air (abſtractedly ſpeaking) require to be noticed, as they very materially affect the accuracy of chemical experiments. *(For theſe ſee the article* GAS.)

AIR *Atmoſpherical*. See ATMOSPHERICAL *Air*.

AIRS *Factitious*. The ſeveral ſpecies of permanent airs or gaſeous vapours, which have been diſcovered by modern chemiſtry, have been termed indiſcriminately *airs* or *gaſſes*. As the latter term is become the moſt familiar, we ſhall merely enumerate in this place the ſeveral ſpecies of air.

Air alkaline, ſee *Ammonia*.

Airs acid, of theſe there are ſeveral ſpecies.

—— *Dephlogiſticated nitrous*, ſee *Nitrous oxyd*.

—— *Dephlogiſticated marine*, ſee *Oxymuriatic acid*.

—— *Vitriolic acid*, ſee *Sulphureous acid*; and for the reſt ſee the reſpective acids.

Air fixed, or *mephitic*, *Aerial acid* of Bergman, ſee *Carbonic acid*.

Air phlogiſticated, or *Atmoſpherical Mephitis*, ſee *Azot*.

Air inflammable, ſee *Hydrogen*.

Air heavy inflammable, ſee *Carburetted Hydrogen*.

Air hepatic, ſee *Sulphuretted Hydrogen*.

Air vital, empyreal, or *dephlogiſticated*, ſee *Oxygen*.

AIR HOLDER. An article of chemical apparatus. (See *the Appendix*.)

ALABASTER. See GYPS.

ALAUNERDE, *Alum earth*, or *Pyritaceous clay*. *Argilla aluminaris bituminoſa, Wern. Terre alumineuſe*, Fr.

The colour of this mineral is browniſh black, or dun blackiſh brown. Sometimes, though rarely, greyiſh black. It occurs amorphous in large ſtrata, and is of a middle conſiſtence between hard and crumbly. Internally it is generally glimmering, on account of a few ſcattered particles of mica, but is ſometimes wholly without luſtre. Its fracture in ſmall pieces is

[a] An. de Chim. tom. 34. p. 133.

earthy and even, but in mafs is flaty, fometimes paffing into flat conchoidal. Its fragments are irregular, blunt-cornered. Its ftreak has a feeble luftre. It is very foft, and may be rubbed to powder between the fingers; is brittle, and of very little elafticity. Sp. gr. according to Kirwan, 1.75.

When placed among burning coals, it generally blazes a little; and when moiftened and expofed to the air in large quantities, it heats, and not unfrequently inflames. From 100 parts of it after torrefaction, Klaproth obtained 10 alum, 7.25 fulphated iron, 2.25 fulphated lime, and 1 fulphated magnefia.[a] Alum-earth is found in Sweden, in Saxony, Bohemia, Hungary, and Auftria, in all which places it is employed in the manufacture of alum.

Its oryctographical fituation is in alluvial ftrata, where it occafionally forms very extenfive beds. It alternates ufually with flate clay, bituminous fchiftus, fand-ftone, and other alluvial minerals, but efpecially with bituminous fchiftus and bituminous wood: it appears indeed to be a natural mixture of thefe two fubftances, the latter of which is not unfrequently difperfed through it. Sometimes pyrites and felenite are mingled with it, and thefe fubftances are often accompanied with native alum, hair falt, and mountain butter. The alum-earth itfelf, indeed, when expofed for a time to the action of the air, becomes covered with a mealy faline efflorefcence, which may be recognifed for native alum, by its ftyptic tafte.[b]

ALAUNSCHIEFER, *Alum-ftate*, *Aluminous Schiftus*. *Ardoife Alumineufe*, *Schifte Alumineufe*. Fr. There are two varieties of this mineral.

Var. I. *Gemeiner Alaunfchiefer*. *Common Alum-ftate*. *Argilla aluminaris fchiftofa vulgaris*. Its colour is greyifh or browniih black, fometimes a middle tint between greyifh and bluifh-black: the furface is not unfrequently iridefcent. It occurs amorphous, or in the form of concentric balls. Internally it is either dull, or glimmering, or little fhining with a common luftre. Its fracture is ftrait-flaty, paffing into the earthy-uneven. It flies when broken into broad fhivers: gives a dull black or grey ftreak; is foft, brittle, and but little elaftic: and has a meagre feel. By expofure to the air it acquires a whitifh efflorefcence, and then has the fweet ftyptic tafte of alum. Sp. gr. 1.8—2.5.

It is frequently penetrated by veins of quartz, and mixed with pyrites.

Alum ftate is found in Great-Britain, Sweden, Germany, Hungary, and fome parts of France, and is largely employed in the manufacture of alum.[a]

Var. II. *Glanzender Alaunfchiefer*. *Shining Alum-ftate*. *Argilla aluminaris fchiftofa nitida*. Wern.

Its colour is between bluifh and greyifh black, paffing into iron black. It occurs amorphous or in balls. Its parallel fracture is generally fhining, fometimes even much-fhining, with a greafy luftre approaching to the metallic: its crofs fracture is dull. Its fracture is thick, or thin, and for the moft part curved, flaty: the fragments are fhivery. It feels fmooth: is half hard, brittle, and but little elaftic. It is a confiderably richer ore of alum than the preceding variety, and is found in the fame countries, though not fo plentifully.[a]

ALAUNSTEIN. *Alum-ftone*. *Calcareus Aluminaris*, Wall. *Pierre calcaire Alumineufe*. *Pierre Alumineufe de la Tolfa*. Fr. *Argilla Aluminaris Tolfenfis*. Wern.

The colour of alum-ftone is for the moft part greyifh or yellowifh white, paffing into Ifabella yellow, or light-yellowifh or fmoak-grey. Sometimes alfo it is found of a tint between flefh and tile-red, or fpotted with ochre-yellow. It occurs amorphous, in confiderable maffes. Internally it is dull, very rarely glimmering. Its fracture is fine-grained uneven, approaching on one hand to earthy, and on the other to fplintery or obfcurely conchoidal: when broken, it flies into indeterminate fharp-cornered fragments. It exhibits fometimes coarfe granular, fometimes conchoidal diftinct concretions. It is tranflucid at the edges: is half-hard, paffing into hard; brittle; flightly adherent to the tongue; meagre to the feel, and gives an argillaceous odour when moiftened. Sp. gr. according to Kirwan, 2.424.

When thrown on a red hot iron it hiffes, gives out a black fmoak, a flight fulphureous fmell, and the remainder acquires a reddifh colour. It does not effervefce with acids: before the blow-pipe it melts to a greyifh clay.

According to Bergman's analyfis it contains,

35	Alumine.
22	Silex.
43	Sulphur.
100	

The refult of Monnet's analyfis was,

50	Alumine
40	Sulphur
—	with a little Iron and Potafh
90	

[a] Klaproth, Analyt. Efs. [b] Emmerling Lehrbuch der Mineral. ii. p. 436. [a] Emmerling jj. p. 441. [a] Emmerling v. jj. 443.

La Metherie[a] is of opinion, that this mineral is principally alum ſuperſaturated with its earth, and therefore earthy and inſoluble in water; an opinion which is ſingularly confirmed by the late analyſis of ſpecimens from La Tolfa, by Vauquelin,[b] who found

43.92	Alumine
25.	Sulphuric acid
3.08	Potaſh
4.	Water
24.	Silex
100.	

This is a rare mineral, being found only at La Tolfa in the States of the Church, in Tuſcany, and Upper Hungary.

At La Tolfa the alum-ſtone is found in large ſtrata, and large maſſes among compact iron-ſhot argillaceous lime-ſtone, and is mixed with lithomarga, fluor, and calcareous ſpars, and penetrated by veins of quartz. In Hungary, pyrites, native ſulphur, and quartz, are often found diſperſed through it.

A volcanic origin has been attributed to it, but apparently without reaſon, as the veins of La Tolfa have been traced into the Appennines.

It is an extremely valuable ſubſtance, being the material from which the pure Roman alum is prepared.[c]

ALBUM GRÆCUM, an antient and abſurd name given to the dung of dogs; formerly uſed for medicinal purpoſes, but now deſervedly laid aſide. As a part of animal chemiſtry however, the properties of EXCREMENT are not to be overlooked, being of no ſmall importance in ſome manufactures, particularly in the preparation of leather, and in ſome of the proceſſes connected with dying and bleaching.

ALBUMEN. *Albumine*, F. *Eyweiſtoff*, G.

One of the immediate conſtituent parts of animal bodies which is to be diſcovered in a vaſt variety of organs, and by its general uniformity and comparative ſimplicity of compoſition, deſerves to be ranked among the more elementary ſubſtances, is that which has been properly termed albumen. It derives this name from being found in great purity in birds eggs, forming the clear, colourleſs, viſcid fluid, called, when coagulated, the white.

White of egg is a clear, viſcid, colourleſs liquid, with ſcarcely any taſte and ſmell. Even when freſh it contains an exceſs of ſoda, ſo that it changes the blue of ſyrup of violets to green. It is perfectly miſcible with any quantity of pure water.

The moſt ſtriking property which characterizes this and the other liquid albuminous liquors, is its power of coagulating into a white elaſtic maſs on the ſimple application of heat. A temperature of about 160° is ſufficient for this purpoſe. The preciſe cauſe of this kind of coagulation is unknown, and it is one of the moſt ſingular properties that can exerciſe the attention of the chemiſt, being excluſively confined to this animal ſubſtance. It has been very erroneouſly attributed to the abſorption and fixation of oxygen, for this proceſs will take place equally ſoon in cloſe veſſels, and under circumſtances where it is impoſſible to trace the ſmalleſt operation of the oxygenous principle. Carradori[a] found that white of egg coagulated very readily under a ſtratum of olive oil, and during its fixation no kind of gas was either given out or abſorbed. Neither was there any apparent difference of bulk between the fluid and the fixed albumen, for the level of the liquid by which it was confined in a narrow tube, did not alter in any degree by coagulation.

Scheele relates a circumſtance, by which he infers (though not quite in a ſatisfactory manner) that coagulation depends on the chemical union of caloric. If two portions of white of egg, previouſly diluted with four parts of water, are ſeparately mixed with carbonated and with cauſtic potaſh, and muriatic acid afterwards added, the ſolution in carbonated alkali will remain clear, whilſt the other will depoſit much of the albumen in white coagulated flakes. The reaſon he explains to be that during ſaturation of the cauſtic alkali with an acid, heat is given out, which immediately fixes the albumen, but no encreaſe of temperature occurs with the carbonated alkali. The reaſon of previouſly mixing water with the egg is to prevent the heat generated by the mixture from becoming ſenſible.

If white of egg is mixed with as much as eight times its bulk of cold water, and well agitated, it does not coagulate with the ſame eaſe, but the albumen ſeparates only gradually, in the form of tough pellicles, on the top of the liquid, ſucceſſively produced.

All the acids coagulate this ſubſtance, the ſtrong ones almoſt immediately. An exceſs of the mineral acids rediſſolves much of the newly formed coagulum, which is not the caſe with the vegetable acids. The addition of water to the clear acid ſolution, again precipitates part of the albumen; but if this is previouſly mixed with much water, the addition of the ſtrongeſt acid only coagulates it.

[a] Theorie de la Terre, ii. p. 215. [b] An. de Chim. tom. 22. p. 275. [c] Lenz. verſuch der Miner. Emmerling, ii. p. 445. Kirwan's Mineralogy. [a] An. Ch. tom. 29.

The alkaline and earthy ſalts produce no change on liquid albumen, but the metallic ſalts coagulate it ſooner or later.

The tanning principle produces coagulation, or rather a chemical ſeparation, for when an infuſion of oak bark is added to recent albumen, a precipitate is immediately formed.

Alcohol very ſpeedily fixes albumen, even when much diluted.

Two other animal liquids contain fluid albumen in conſiderable quantity; they are the ſerum of BLOOD and MILK. The cheeſe or curd of milk agrees in every property with coagulated white of egg, and is ſeparated from the watery part by the ſame means, only it is in a ſtate of very dilute ſolution.

The morbid affuſion of water in dropſy, is ſometimes almoſt entirely albuminous.

The further analyſis of albumen refers more particularly to its coagulated ſtate.

The albumen of eggs,[b] if expoſed to a moderate heat, not exceeding that of boiling water, in a dry place, ſoon ſhrinks very conſiderably, and at the ſame time becomes very hard, brittle, yellow, and ſemi-tranſparent like horn; after which it undergoes no further ſpontaneous change. This horny matter, if digeſted in boiling water, in a few hours is ſoftened, and becomes again white, like freſh coagulated white of egg, after which it may be kept in boiling water for many days, without further change. The water in which it has boiled is not altered by oak bark ſolution, but very ſlightly by nitro-muriate of tin, ſhewing that the long coction has only diſſolved an extremely ſmall portion.

With acids ſome peculiarities are to be obſerved, which are of uſe in the minutiæ of analyſis.[c]

The ſulphuric acid has very little effect on ſolid albumen, except heated, when the albumen is charred and blackened, as is the caſe with moſt animal matters in theſe circumſtances.

When long ſteeped in cold muriatic acid, it gradually becomes of a dark purple or blue colour. This change takes place in eight or ten days, after which no further effect is produced for many weeks or months. Very little of the albumen is diſſolved by this proceſs. Nitric acid changes this colour to a yellow.

Immerſed in cold nitrous acid, rather dilute, the albumen is gradually ſoftened and opened in its texture, and if afterwards taken out, waſhed, and boiled in diſtilled water, it entirely diſſolves into a pale yellow liquid, which aſſumes the form of a thick jelly by ſlow evaporation, and is *now* again ſoluble in water. So that the effect of this powerful acid is to bring it nearly to the ſtate of gelatin, and the watery ſolution is equally precipitable by tanning.

If the nitric acid be concentrated, or eſpecially heated, the whole is rapidly diſſolved with extrication of nitrous fumes, and pruſſic acid, forming as before a yellow nitrous ſolution. Ammonia added to theſe ſolutions turns them of an orange or red colour, without forming any precipitate, and the ſolution is now ammoniacal.

All the alkalies when cauſtic, readily diſſolve albumen. The fixed alkalies boiled with it, produce a true animal ſoap, and during the proceſs much ammonia is given out. This ſoap diſſolved in diſtilled water and filtrated, gives a copious precipitate on adding the muriatic or acetous acid. This precipitate is at firſt viſcid and yellow, and on chemical examination appears to be the original albumen, little altered in its properties, except by being rendered rather more ſoluble in water.

Albumen expoſed, per ſe, to deſtructive diſtillation, affords ſome water, carbonated ammonia, a fœtid empyreumatic oil, carbonated hydrogen gas, carbonic acid gas, and pruſſic acid. A ſpongy coal of a grey metallic luſtre remains, which it is extremely difficult to burn to aſhes, as the proceſs is conſtantly ſtopped by a vitreſcent coating which forms around it. From 500 grains of dry albumen, Mr. Hatchett obtained 74.5 grains of reſidue, of which 63.25 were mere coal, and the remaining 11.25 conſiſted of phoſphat of lime, phoſphat of ſoda, and a little carbonat of lime.

Liquid albumen putrifies with eaſe when expoſed to a warm and moiſt air. It is not ſo however with the coagulated, for in this form it may be preſerved, even though white and ſoft, for ſeveral weeks in water without becoming very putrid, or at all broken down by this proceſs; and indeed the truly albuminous parts of the body are among the leaſt alterable ingredients of the animal frame. No acid is generated by liquid albumen during its putrefaction.

From the experiments of the excellent chemiſt above mentioned, which make part of a moſt intereſting ſeries of reſearch on the variety of organs provided for the covering or protection of the living animal, it fully appears, that albumen exiſts almoſt pure in the horn, nail, flexible ſhell, hair, feather, and ſimilar organs; that no aſcertainable difference can be detected between the albuminous part of theſe, and the coagulated

[b] Hatchett. Phil. Tranſ. vol. 90. [c] Hatchett.

white of egg; that it is diſtinguiſhed from gelatin chiefly by its difficult ſolubility in water, even when not ſo denſe in texture as the firmeſt gelatinous organs, by its very ſlow putreſcibility, and eſpecially by its forming a true ſoap with the cauſtic alkalies, a property not in any degree poſſeſſed by animal gelly. See GELATIN.

The vegetable kingdom is not deſtitute of its albumen, though from being more abundantly found in the animal, it has been termed, when vegetable, *vegeto-animal*. Fourcroy[*] obſerved this ſubſtance in the expreſſed juice of many of the cruciform plants, ſuch as the creſs, ſcurvy-graſs, &c. in cabbage juice, and in general it may be preſumed to exiſt in thoſe vegetables that exhale a putrid odour when dead and expoſed to circumſtances favourable to putrefaction.

The freſh juice preſſed from the leaves and ſtalks of theſe plants, is at firſt green and turbid, and therefore, as pure albumen uncoagulated is quite limpid, the colouring matter muſt be another ſubſtance united with it. This has been termed the green FECULA, and is ſeparable to a great degree by filtration, and by mere expoſure to the air for ſome hours. After this, if the clarified juice be now heated in boiling water, a grey coagulum is ſeparated in ſmall curdy lumps, which agrees with albumen in all its properties of coagulability by heat, ſolubility in alkalies, and ready putreſcency without the intermediate formation of an acid.

A ſimilar albuminous matter is found in wheat flour. If this is worked up with cold water in the hands, into a very tenacious paſte, and a ſmall ſtream of water is ſuffered to drop through the paſte, agitating it all the while with the fingers, the water runs off it for ſome time quite white and turbid, till at laſt every thing ſoluble in this fluid, or miſcible with it, is extracted from the paſte, and a very tenacious GLUTEN is left in the hands. The white fluid, by reſt, depoſits the ſtarch or fecula, and the ſupernatant liquid remains clear. On expoſing this clear fluid to a boiling heat, a white flocculent coagulum ſeparates, which exhibits all the properties of albumen.

In the animal kingdom, albumen appears to be one of the primary conſtituent principles, and its characteriſtic properties are, on the whole, ſufficiently obvious to make it a very promiſing ſubject for reſearch to the chemical phyſiologiſt.

ALCOHOL, or SPIRIT OF WINE. *Eſprit de Vin*, F. *Weingeiſt*, G.

This is the conſtant and moſt characteriſtic product of the vinous fermentation, produced equally from all fermented intoxicating liquors, by the proceſs of diſtillation.

When pure, alcohol has the following properties: it is perfectly limpid and colourleſs as water, has a ſtrong penetrating agreeable odour, and a very hot fiery taſte, which, however, ſpeedily leaves the tongue; when ſhaken in a glaſs veſſel, it ſhews very large bubbles, which almoſt inſtantly diſappear. It is much lighter than water, oil, acids, or moſt liquors with which we are acquainted. The actual ſpecific gravity varies very conſiderably, according to the means employed for its purification, ſo that the extreme term of levity has not been fixed with perfect accuracy. The weight of the lighteſt alcohol, procurable by ſimple diſtillation, without any addition, is about .825 at 60° of temperature, and by means, which we ſhall preſently mention, it may be brought as low as .813, or perhaps ſtill leſs. On account of its great tenuity and liquidity, it appears remarkably mobile when ſhaken.

Alcohol is incapable of congelation in any degree of cold, natural or artificial, which has hitherto been obſerved, and therefore it retards in a high degree the congelation of other liquors with which it is mixed. So, equal parts of alcohol and water require a cold of —6° to be frozen; and if any common fermented liquor be expoſed to froſt, only the watery part will at firſt freeze, whilſt the ſpirituous portion remains in the liquid, and cauſes it to reſiſt a much greater cold than before.

Alcohol evaporates with very great facility at a much lower temperature than water. Held in the warm hand, it ſoon flies off, producing by its evaporation (as by all converſions of fluids into the gaſſeous form) a degree of cold, which in this inſtance is very conſiderable. It evaporates long before it actually boils. The latter takes place when it is heated to about 165°, and this boiling point is higher as the ſpirit is more watery, ſo that brandy, a weaker ſpirit, boils at about 180°. The vapour, in condenſing, exhibits on the ſides of the veſſel a peculiar long ſtreak, which is very characteriſtic. Its readier evaporation than water furniſhes an eaſy method of dephlegmating it, or depriving it of water, by the mere application of well regulated heat. When once pure, it is unalterable by any number of ſucceſſive diſtillations, if without addition.

Alcohol when poured gently on the ſurface of water, will remain on its ſurface for a con-

[*] An Chim. Tom. 3.

ſiderable time, without mixing with it, ſo great is the difference of their reſpective gravities; but on ſhaking them together they rapidly unite, extricating numerous minute bubbles, and a degree of heat very ſenſible to the hand if a few ounces of each are uſed, and the veſſel that contains them not too thick. At the ſame time a mutual penetration takes place, ſo that the ſpace occupied by the liquors after mixture, is leſs than when ſeparated. Hence too the ſpecific gravity of the mixture is greater than the mean gravity of each liquor ſeparately taken, which forms the foundation of many intereſting experiments on the gravity of ſpirit and water, which we ſhall preſently mention. The mutual penetration is ſhewn very ſtrikingly in the following manner: procure a thick glaſs barometer tube, with a bulb blown at one extremity, capable of holding four or ſix ounces of water, pour down through the narrow end (holding the glaſs with the bulb downwards) about as much water as will half fill the bulb, upon this pour alcohol, coloured very red with litmus, or any other dye, without ſhaking the tube, and fill it nearly to the top, when the coloured ſpirit will be ſeen to reſt on the ſurface of the water unmixt: mark on the outſide of the tube the height to which the ſpirit reaches; then, ſtopping the open end with the finger, ſhake the bulb violently, ſo as to cauſe the liquors to mix; the glaſs will feel ſomewhat warm to the hand, and the level to which the mixed liquid riſes in the tube, will now be found at leaſt an inch or two lower than when unmixed.

Spirit of wine of almoſt any degree of ſtrength, readily catches fire when a lighted ſubſtance is applied, the eaſier, the greater is the ſtrength. It burns with a pale flame, blue on the outſide, and white in the center, but ſo faint as ſcarcely to be viſible in day-light. If the alcohol is highly pure or free from water, every particle of it is conſumed, but if watery, the ſpirituous part only burns, and the fire goes out as ſoon as this is nearly conſumed. It does not require any wick to be ſet on fire, but if a wick is uſed it is ſcarcely injured by the flame in contact with it. The burning glaſs will not kindle it. The combuſtion of ſpirit of wine has this peculiar circumſtance, that it is unattended with ſmoke, or any kind of fuliginous vapour, ſo that the brighteſt metal plate held over it, is not ſoiled with the flame: neither does the reſidue of combuſtion contain any coaly matter, the whole products of this proceſs being only carbonic acid and water.

The flame of alcohol may be beautifully coloured by the addition of various ſubſtances; all the ſalts of copper give it a fine emerald green; boracic acid, or borax, a greeniſh yellow; nitre and ſome other neutral ſalts, a dun yellow; and the ſoluble ſalts of ſtrontian a deep blood red.

Spirit of wine is immediately obtained by the proceſs of diſtillation from every ſpecies of ardent ſpirits. The latter again, are the products of a previous diſtillation of any liquor which has undergone the vinous fermentation, ſo that at leaſt two diſtillations are requiſite to obtain the purely ſpirituous part of vinous liquors. We ſhall refer to the articles SPIRITS *Diſtilled*, the many important obſervations to be made on the buſineſs of the diſtillery, and the manufacture of brandy, rum, and malt ſpirits; and ſhall here only deſcribe the chemical proceſs of *rectification*, or the preparation of alcohol from theſe ſpirits.

The ſimpleſt proceſs is the following: Put any quantity of brandy or malt ſpirits, or rum, diluted with as much water, into an alembic, (and better furniſhed with a water bath, as deſcribed in the Appendix, though this is not abſolutely neceſſary) join to it the refrigeratory, and diſtill with a gentle heat. The firſt product is invariably the ſtrongeſt and pureſt. The ſpirit continues to come over colourleſs, but gradually diminiſhing in ſtrength and purity, till at laſt it is ſo watery as no longer to take fire by a lighted match. After this, if the diſtillation be continued, the liquor becomes milky, ſcarcely ſpirituous to the ſmell, and of a ſouriſh taſte. In this proceſs no advantage is gained by continuing it after the liquor is no longer inflammable, which happens when about $\frac{3}{4}$ or $\frac{4}{5}$ of the whole contents of the alembic have paſſed over. If the firſt fourth or third of the diſtilled ſpirit be ſet apart, it forms a moderately ſtrong alcohol, and the remainder, one more dilute, which will ſerve for many purpoſes.

Simple diſtillation will therefore ſeparate the alcohol of any ardent ſpirit from the water, colouring matter and accidental impurity, but there are two principles which are not entirely got rid of in this manner, they are, an empyreumatic flavour often given by a careleſs or too haſty previous diſtillation of the ſpirit, and a ſtrong, often fœtid oil, which the ſpirit has diſſolved, either out of the caſk in which it is kept, or from ſome of the materials of fermentation, or from intentional additions by the manufacturer. The flavour of this oil is beſt

perceived on rubbing ſome of the ſpirit on the warm hands, whereby it readily evaporates, and a ſtale nauſeous ſmell, like the breath of drunkards, is left. The mere empyreuma, or burnt ſmell, goes off in a great degree by keeping in charred caſks, but the oil more obſtinately adheres [b]

The obſervations of Beaumé [c] on this ſubject are valuable. This moſt accurate chemiſt remarks that many wines, and brandies made from theſe wines, are naturally more oily than others, and retain this flavour through ſucceſſive diſtillations; the rich Spaniſh wines much more ſo than the French, and hence they ſhould be avoided in the preparation of pure alcohol. A large and repeated dilution with water, and diſtillation after each dilution, will indeed very effectually ſeparate the oil (as may be obſerved by adding water to the ſpirituous ſcented eſſences, which will make them turbid, and the flavouring oil will ſwim at the top), but this proceſs is tedious and embarraſſing from the quantity of weak liquid. Dilution with water, filtration through quick-lime in cloſe veſſels, and ſubſequent diſtillation, will anſwer very well if the quantity of oil is not too great; having been, as Beaumé obſerves, an old practice with the Pariſian liquor-merchants, who, to eſcape the barrier duty on raw ſpirits, uſed to convert it into ſcented ſpirits by the addition of a little eſſential oil, and afterwards, by the above means, reſtore it to its original ſtate of ſimple ſpirit.

Alum, ſea ſalt, Glauber's ſalt, calcined bone, chalk, toaſted crumb of bread, and many other ſubſtances have been added, during diſtillation, to keep down the oil, all of them with conſiderable but not compleat ſucceſs.

Alkalies and lime remove it entirely, but with ſome alteration of the ſpirit itſelf, as we ſhall preſently mention.

Beaumé recommends the following judicious management in diſtillation, to obtain part of the ſpirit conſiderably freed from the oil: it is founded on the fact that the firſt portion diſtilled contains ſcarcely any oil, but the latter product is almoſt ſaturated with it. Heat brandy in an alembic as uſual, and when about a quarter of the liquor has paſſed, ſet it aſide, and continue the proceſs as long as the ſpirit is inflammable. This latter ſpirit re-diſtill as before, ſeparating the firſt from the laſt product. Still repeat the diſtillation on the laſt product of the foregoing proceſs, as long as the firſt quarter of the product comes over tolerably pure. Then mix all the firſt products together and diſtill, reſerving the firſt half for the pureſt alcohol, and the laſt for ordinary purpoſes. Thus the oil is conſtantly concentrated into the latter diſtilled portions, whilſt the firſt are obtained proportionably purer.

We have mentioned that ſimple diſtillation of alcohol, however often repeated, and only the firſt product reſerved, will yield a ſpirit of the ſpecific gravity of about .825 at 60°, but the higheſt concentration is given by the uſe of alkalies or lime, or in ſome degree by any ſalt which has a very ſtrong affinity with water; and the two former have the additional advantage of deſtroying the empyreumatic oil, though the alkalies are apt, in return, to communicate ſomewhat of an urinous flavour.

Though both the carbonated and cauſtic alkalies have the effect of concentrating alcohol, a difference takes place in their action on this liquid. The carbonated alkalies are inſoluble in the ſpirit, but the cauſtic alkalies compleatly diſſolve in it. If to a weak ſpirit is added ſome dry carbonated potaſh, and ſhaken together, the alkali becomes diſſolved only in the water of the ſpirit, and thus two liquors appear of very different ſpecific gravity, and abſolutely immiſcible by agitation. The lower liquor is the alkaline ſolution, the upper the alcohol, now rendered ſtronger by the loſs of the water, which the alkali has ſeparated from it. If the alcohol alone be poured off, and mixed with a freſh quantity of dry carbonated potaſh, the alkali will again either entirely diſſolve, or become paſty, according to the quantity of ſuperfluous water left in the ſpirit; if there is none, it will remain at the bottom untouched.

This is a ready way of bringing alcohol to very great concentration without diſtillation, and would anſwer every purpoſe, if it were not that the dry carbonated alkalies (except the cryſtallized) all contain a certain portion of the ſalt, in a ſtate ſufficiently approaching to cauſticity to be ſoluble in alcohol; ſo that in the above proceſs, the liquid ſwimming above the watery ſolution of carbonated potaſh, is not pure ſpirit, but a very weak ſolution of cauſtic alkali in alcohol. To obtain it quite pure, add one part of very hot dry carbonated potaſh (good pearlaſh will do) to about ſix or eight parts of alcohol, already brought to conſiderable ſtrength by diſtillation, let them ſtand together for ſome hours, frequently ſhaking them, then diſtill with a gentle heat, and the firſt half or two-thirds of the product is the pureſt alcohol.

[b] Collier Manch. Mem. vol. v.

[c] Elem. de Pharmacie.

Or, with leſs trouble, add one part of the alkali to four parts of brandy, and diſtill after ſtanding together for about a day; but the former proceſs is the beſt.

Burnt alum, dried Glauber's ſalt, or decrepitated common ſalt may be very conveniently ſubſtituted for the carbonated alkali.

Hot, dry, cauſtic alkali is ſtill more efficacious in ſeparating the water from the alcohol, which, carefully diſtilled, is extremely pure. But cauſtic alkalies, as well as lime, decompoſe ſo much of the alcohol, in the way that will be afterwards mentioned, as to render it both a waſteful proceſs and one that requires more care in conducting it.

By the above means the levity and proportionable dephlegmation of alcohol may be brought from the ſpecific gravity of .825 at 60° of heat, to about .813 ° or perhaps ſtill higher. Malt ſpirits yield as ſtrong and pure an alcohol as wine brandy.

Various methods have been employed for aſcertaining the ſtrength of ardent ſpirit, but this is attended with more difficulty than might at firſt be imagined. Long habit will enable a perſon to judge with tolerable accuracy by the taſte, and the frothineſs and ſize of the bubbles when ſhaken, but this is obviouſly liable to error. The teſt of burning the ſpirit has long been uſed, and with proper precaution it may be brought to ſome degree of accuracy. It has been already mentioned that a very pure alcohol will burn away without leaving any reſidue, and that the weaker the ſpirit is, the more water will be left after combuſtion. In many countries this trial is actually performed in the following ſimple manner.[d] A cylindrical ſilver cup, properly gradulated and made for this purpoſe, is filled to a known height with the ſpirit, which is then kindled, and is ſuffered to burn till the flame goes out, after which the quantity of watery reſidue is noted. Pure alcohol leaves none, rectified ſpirit of moderate ſtrength about 25 per cent, French brandy about 56, common good malt ſpirit about 65, and the like. The principal imperfection of this method, is the difficulty of always performing the experiment under ſimilar external circumſtances: and beſides it is by no means proved that the combuſtion of compound ſpirits will follow the ſame rules as that of ſimple mixtures of alcohol and water. In this trial the reſidue ſtill contains a portion of alcohol, the combuſtion ceaſing before all the ſpirit is burnt off; but on the other hand, ſome of the water muſt neceſſarily have been evaporated by the heat of combuſtion.

Another trial, though extremely incorrect, is to pour a few drops of the ſpirit on a very ſmall heap of gunpowder, and kindle it. The ſpirit firſt burns as uſual, and when the laſt portion is burning off, the powder explodes, if the ſpirit has not been too watery to leave the powder very damp. Cotton wool burns in like manner at the end of the combuſtion of the ſpirit, if not too damp. But it is well known that a little heap of powder drenched with even a ſtrong ſpirit, will not take fire, and a large heap will explode if only a few drops of a watery ſpirit is uſed. Beſides, theſe teſts, were they accurate, would only indicate two degrees of ſtrength, that which would fire the powder, and that which would not.

Another teſt, ſufficiently accurate for a rough eſtimation of the ſtrength of the ſpirit, is to ſhake it in a bottle with ſome dry carbonat of potaſh, and to judge of its ſtrength by the quantity of water which the alkali attracts from it.

A ſpirit that ſwims in olive oil has ſometimes been conſidered as proof, and this method is actually uſed in the manufacture of rum, but this teſt alſo only indicates two degrees.

The only mode of aſcertaining the relative ſtrength of every ſpecies of ardent ſpirit, with any conſiderable accuracy, has been by determining its ſpecific gravity; and the high public importance of the ſubject in countries where the conſumption of ſpirits adds a vaſt ſum to the public revenue, has been the means of inſtituting many very intereſting ſeries of experiments to this purpoſe.

As our limits will not allow a complete notice of all that has been done on this ſubject in different countries, we ſhall principally confine ourſelves to the very minute, accurate, and every way excellent ſeries of experiments made for the Honourable Board of Exciſe, by Sir Charles Blagden, aſſiſted by Mr. Gilpin, and publiſhed in the 79th and 82d volumes of the Philoſophical Tranſactions.

Their object was to determine by actual experiment, the ſpecific gravity of mixtures of different proportions of alcohol of a determinate ſtrength, with pure diſtilled water at different degrees of the thermometer; and theſe experiments were carried to a minuteneſs much more than neceſſary even for the high duties now levied on ſpirits, where a trifling

[c] Blagden Phil. Tranſ. [d] Leonhardi's Macquer's Worterbuch.

difference in ſtrength becomes an object of attention.

It is aſſumed as a principle in the preſent mode of laying the duties, that all kinds of diſtilled ſpirits contain an equal proportion of real alcohol with a mixture of pure alcohol and water, brought to the ſame ſpecific gravity, and therefore it is on the abſolute quantity of alcohol in any mixture that the duty is levied. This poſition though ſufficiently accurate for the purpoſes of the revenue, is not abſolutely true; ſince ardent ſpirit will diſſolve various ſubſtances, ſuch as ſugar, colouring matter, &c. the effect of which ſolution will be to encreaſe its denſity, and therefore to make it appear to contain leſs alcohol than is really the caſe.

The whole expanſion of alcohol[a] as pure as ſimple diſtillation will give, when raiſed from the temperature of 30° to 100° is about one-twelfth of the bulk which it had at 30°; and within this range the expanſion is pretty equal for equal increments of heat. On the other hand, the expanſion of water within the ſame range of from 30° to 100° is only $\frac{1}{245}$ of its bulk at 30°. Beſides, a curious property of water, diſcovered by Dr. Blagden, here comes into action, which is, that (contrary to the nature of all other known liquids) it has arrived at its greateſt denſity much before it is cooled down to its freezing point, namely at 40° or 42°, and that between this temperature and 30° its ſpecific gravity regularly goes on diminiſhing till congealed. So that the gravity of water at 30° is found to be no more than at 48½°.

When alcohol and water are mixed, a mutual penetration of the two liquors takes place, as we have already mentioned, and the liquors occupy leſs room mixed than ſeparate, ſo that the ſpecific gravity of the mixture is greater than the mean ſpecific gravity of the two, before mixture. The anomaly in the action of heat on water below 42° has juſt been noted, but another ſource of complication in calculating the denſities of ſpirit and water, ariſes from the following circumſtance: with a heat gradually raiſed from 42° upwards to 100°, water at firſt expands ſlower in compariſon to its entire increaſe, than alcohol; but afterwards, when approaching to the higheſt term of heat, its expanſion is proportionably greater than that of alcohol. Hence it is that a mixture of theſe two liquids will approach the nearer to the progreſſive ratio of expanſion of the one or the other, in proportion as one or the other liquor predominates in the mixture. But, again, the abſolute expanſion will be greater as there is more alcohol in the mixture.

All theſe circumſtances indicated the danger of truſting to mere calculation from a very few data (as had been done by other ſcientific perſons) to compoſe tables of the expanſion of alcohol and water, with even tolerable correctneſs; and hence Sir C. Blagden, and his coadjutor, determined to undertake ſo many actual experiments on the ſpecific gravity of mixtures of alcohol and water, at various temperatures, as to leave but very little room for incorrectneſs in the ſpaces on the ſcale filled up by interpolation. The pure, or ſtandard alcohol, was that of .825 at 60°, being the pureſt obtainable by ſimple diſtillation, lowered a very little by water to bring it to even numbers for the convenience of calculation. The ſpecific gravity was taken, in every caſe, by filling the ſame bottle to a known height with the ſpirit, and weighing it. To enſure a perfect penetration of the ſpirit and water, they were never uſed till they had been mixed for a month, and often ſhaken. The extreme precautions taken to enſure as great accuracy as human inſtruments can command, are given in detail in the original memoirs. The actual experiments were, the ſpecific gravities, firſt of the pure ſpirit, then of 100 parts of it (by weight) with every five parts of water, from 5 to 100, and laſtly of 100 parts of water with every five parts of ſpirit; all of them taken at every fifth degree of heat, from 30 to 100. The intermediate degrees, both of temperature and of proportion of water or ſpirit, are filled by interpolation.

The following Table, extracted from Mr. Gilpin's corrected tables, in the 82d vol. of the Philoſophical Tranſactions, will apply to moſt caſes which may be wanted in chemical enquiry.

[a] Blagden.

TABLE of the Specific Gravity of Mixtures of Alcohol and Water, at different temperatures.

Heat	Pure Alcohol.	One hundred parts (by weight) of pure Alcohol with 5 Water	10 Water	15 Water	20 Water	30 Water	40 Water	50 Water	60 Water	70 Water	80 Water	90 Water
40°	.83445	.84539	.85507	.86361	.87134	.88481	.89617	.90596	.91428	.92151	.92783	.93341
45	.83214	.84310	.85277	.86131	.86907	.88255	.89396	.90380	.91211	.91937	.92570	.93131
50	.82977	.84076	.85042	.85902	.86676	.88030	.89174	.90160	.90997	.91723	.92358	.92919
51	.82929	.84028	.84994	.85855	.86629	.87984	.89128	.90115	.90952	.91679	.92316	.92877
52	.82881	.83980	.84946	.85808	.86582	.87937	.89083	.90069	.90906	.91634	.92274	.92835
53	.82833	.83932	.84898	.85760	.86535	.87890	.89037	.90024	.90860	.91590	.92231	.92793
54	.82784	.83883	.84859	.85712	.86488	.87843	.88991	.89978	.90814	.91546	.92189	.92751
55	.82736	.83834	.84802	.85664	.86441	.87796	.88945	.89933	.90768	.91502	.92145	.92707
56	.82689	.83787	.84756	.85618	.86395	.87750	.88900	.89887	.90724	.91459	.92102	.92666
57	.82642	.83740	.84709	.85571	.86348	.87704	.88855	.89842	.90681	.91416	.92059	.92625
58	.82594	.83693	.84662	.85521	.86302	.87659	.88810	.89797	.90638	.91373	.92019	.92583
59	.82547	.83646	.84615	.85477	.86256	.87614	.88795	.89752	.90595	.91330	.91975	.92541
60	.82500	.83595	.84568	.85430	.86208	.87569	.88720	.89707	.90549	.91287	.91933	.92499
61	.82453	.83552	.84520	.85382	.86162	.87523	.88674	.89662	.90504	.91242	.91890	.92455
62	.82405	.83504	.84473	.85335	.86115	.87476	.88628	.89617	.90460	.91198	.91847	.92412
63	.82357	.83457	.84426	.85288	.86069	.87430	.88582	.89571	.90416	.91154	.91803	.92369
64	.82310	.83409	.84379	.85241	.86022	.87384	.88536	.89525	.90372	.91110	.91759	.92326
65	.82262	.83362	.84334	.85193	.85976	.87337	.88490	.89479	.90328	.91066	.91715	.92283
66	.82214	.83315	.84286	.85145	.85928	.87291	.88443	.89433	.90284	.91023	.91670	.92241
67	.82167	.83268	.84237	.85096	.85880	.87245	.88395	.89387	.90239	.90978	.91625	.92198
68	.82119	.83221	.84189	.85048	.85832	.87198	.88348	.89342	.90194	.90934	.91581	.92155
69	.82071	.83173	.84141	.84999	.85784	.87151	.88301	.89297	.90149	.90890	.91537	.92112
70	.82023	.83124	.14092	.84951	.85736	.87105	.88254	.89252	.90104	.90847	.91493	.92662
75	.81780	.82878	.83851	.84710	.85496	.86864	.88018	.89018	.89872	.90617	.91270	.91849
80	.81530	.82631	.83603	.84467	.85248	.86622	.87776	.88781	.89639	.90385	.91046	.91622

Heat	One hundred parts (by weight) of Water with 100 Alc.	90 Alc.	80 Alc.	70 Alc.	60 Alc.	50 Alc.	40 Alc.	30 Alc.	20 Alc.	10 Alc.
40°	.93827	.94295	.94802	.95328	.95879	.96434	.96967	.97472	.98033	.98795
45	.93621	.94096	.24605	.95143	.95705	.96280	.96840	.97384	.97980	.98774
50	.93419	.93897	.94414	.94958	.95534	.96126	.96708	.97284	.97920	.98745
55	.93208	.93696	.94213	.94767	.95357	.95966	.96575	.97181	.97847	.98702
60	.93002	.93493	.94018	.94579	.95181	.95804	.96437	.97074	.97771	.98654
65	.92794	.93285	.93822	.94388	.95000	.95635	.96288	.96959	.97688	.98594
70	.92580	.93076	.93616	.94193	.94813	.95469	.96143	.96836	.97596	.98527
75	.92364	.92865	.93413	.93989	.94623	.95292	.95987	.96708	.97495	.98454
80	.92142	.92646	.93201	.93785	.94431	.95111	.95826	.96568	.97385	.98367

Beſides the ſpecific gravities here given, the original tables contain ſeveral particulars deduced from the experiments, ſuch as the quantity of real ſpirit in a given bulk of the mixtures, the actual condenſation expreſſed in numbers, and the like. Some of theſe chiefly concern the buſineſs of the exciſeman, but with regard to the condenſation, we ſhall extract the following reſults deduced from the ſame tables.

One hundred parts, in bulk, of the pure ſpirit, at the temperature of 60°, mixed

of water	*parts*	
with 25	diminiſh in bulk 2.31	being about $\frac{1}{341}$ of the whole before mixture
50	3.76	$\frac{1}{403}$
75	4.82	$\frac{1}{363}$
100	5.60	$\frac{1}{357}$
125	6.15	$\frac{1}{365}$
150	6.53	$\frac{1}{382}$
175	6.76	$\frac{1}{406}$
200	6.81	$\frac{1}{446}$

Hence it appears that the greateſt diminution in bulk, or concentration, *in proportion to the quantity of ingredients*, which takes place between alcohol and water, occurs when equal bulks of each are uſed, being more than a thirty-ſixth of the whole; but the greateſt poſſible diminution obtainable by any admixture of water, happens when two parts of water are added to one of alcohol, being 6.81 parts where 100 of alcohol are employed. This laſt is the higheſt term of *actual* diminution, as it is again leſs than 6.81 in 100, if ſtill more water is added.

The following reſults are given by two eminent French chemiſts, who have paid great attention to the ſubject, Briſſon and Beaumé. The experiments of each are made with much leſs minuteneſs, and there is reaſon to believe with leſs accuracy than thoſe of Blagden and Gilpin. Thoſe of Briſſon were only made for one temperature, that of 10° of Reaumur (equal to 54½° Fahrenheit, and the uſual ſtandard heat taken by the French philoſophers for experiments of this kind). Thoſe of Beaumé were taken at every fifth degree of Reaumur, (from 0. to about 100 Fahrenheit.) Beaumé's experiments form the baſis of his graduated ſpirit hydrometer *(peſe liqueur)* which is ſtill employed in France.

Briſſon's Table.

(Heat 54½°. Fahrenheit.)

(The ſtandard Alcohol being .8293 and the mixtures made by weight.)

Alcohol	*Water*	*Sp. Grav.*	*Alcohol*	*Water*	*Sp. Grav.*
16 with	0.	.8293	8 with	8	.9427
15	1	.8527	7	9	.9519
14	2	.8674	6	10	.9598
13	3	.8815	5	11	.9674
12	4	.8947	4	12	.9733
11	5	.9075	3	13	.9791
10	6	.9199	2	14	.9852
9	7	.9317	1	15	.9919
			0	16	1.0000

[f] BEAUMÉ's TABLE.

(Heat 54½° Fahr. The ſtandard alcohol .8276, and the mixtures made by weight,

Alcohol		Water	Degrees of Beaumés Hydrometer	Correſponding Sp. Gravity
16.	with	0.	40	.8276
15		1	37	.8421
14		2	34	.8571
13		3	32	.8675
12		4	29½	.8807
11		5	27	.8944
10		6	25	.9057
9		7	23	.9172
8		8	21	.9290
7		9	19½	.9382
6		10	18	.9474
5		11	16½	.9569
4		12	15	.9666
3		13	14	.9730
2		14	13	.9796
1		15	12	.9863
0		16	10	1.0000

From the above table it appears that the author's ſpirit hydrometer, at the temperature of 10° Reaumur (54½° Fahr.) indicates 40 degrees for the pure ſpirit, which is what the author alſo calls *prodigieuſement rectifié*,[g] or ſpirit rectified by ſimple but repeated diſtillation, the firſt third, or fourth part, of the product only being taken. It is ſatisfactory to obſerve how very exactly this accords with Blagden's ſtandard alcohol, which is procured in the ſame manner, and is ſtated to be at 55°, .82736 ſpecific gravity, ſo that theſe two may be compared in all their gradations. In point of accuracy of inſtruments, however, they are by no means comparable, thoſe of Blagden and Gilpin being extremely delicate, whereas the incompetency of the hydrometer with the varying point of immerſion, to very great accuracy, is now fully admitted. The entire range in this inſtrument is 30 degrees, the zero or point for diſtilled water being marked for 10 degrees. *See the article* HYDROMETER.

To proceed to the chemical compoſition of Alcohol. The remarkable circumſtance of the production of water without any ſmoke or perceptible vapour, from the burning of ſpirits, was early noticed by Juncker, Geoffroy, and Boerhaave; but the reaſon of this phenomenon has been explained, by performing the experiment in the more accurate methods, which are entirely due to modern chemiſtry; namely, by operating upon known quantities in given portions of air, and examining both the products and reſidues of combuſtion. Several modes have been purſued in the analyſis of this ſubſtance, for the proceſs preſents conſiderable difficulties. Lavoiſier attempted to burn a quantity of it in a ſmall lamp, confined in a jar of oxygen gas; but this is attended with no ſmall degree of danger; for if the ſpirit has remained long enough in contact with the oxygen to be in part volatilized and mixed with it, the firſt application of fire to the ſpirit alſo kindles the whole air thus mixed, and cauſes as formidable an exploſion as that occaſioned by firing oxygen and hydrogen gaſſes. Even if the ſpirit be kindled as ſoon as introduced within the oxygen, if the combuſtion goes on rapidly, the heat thereby generated evaporates part of the ſpirit within the jar, which then explodes, as in the former caſe. Only very ſmall quantities of ſpirit can be conſumed in cloſe veſſels, unleſs air be furniſhed to it very gradually whilſt burning, but with this precaution an experiment of ſufficient magnitude may be performed.

Lavoiſier[h] employed for this purpoſe a large bell glaſs, holding from 700 to 800 cubic inches, and inverted over a mercurial trough. A ſmall lamp, filled with a known weight of alcohol, was introduced under the glaſs, ſwimming on the ſurface of the mercury, and the wick was armed with a minute portion of phoſphorus. The common air within the glaſs was ſucked out by a ſyphon, till the mercury roſe to a cer-

[f] Haſſenfratz, An. Chim. Tom. 33. [g] Beaumé, Elem. de Pharmacie. [h] Ency. Meth. Art. Alcool.

tain height, which was noted, and the wick being then kindled the ſpirit took fire. When the flame was weakened, a freſh ſupply of air was ſent into the bell-glaſs from a reſervoir of oxygen gas, through a ſyphon tube, and this was kept up with great precaution, till the quantity of carbonic acid generated was ſo great as to extinguiſh the flame. On examining the reſults, it was found that 93.5 grains of alcohol and 110.32 grains of oxygen had been expended in the combuſtion. The products were 93.8 grains of carbonic acid, and 106.2 grains of water, ſo that the quantity of water *exceeded by 12.7 grains the entire quantity of the alcohol.* From theſe data, and from previous experiments on the proportion of oxygen required to convert carbon into carbonic acid, and hydrogen into water, Lavoiſier concluded the compoſition of the alcohol, on which he operated, to be as follows:

Carbon - - - - - - - - - -	28.53
Hydrogen - - - - - - - - -	7.87
Water (already exiſting in the alcohol)	63.6
	100.00

Whatever doubts may be thrown on the entire accuracy of the numbers here given, two principal points are aſcertained to be the leading objects of remark in the analyſis of alcohol by combuſtion, namely, the production of carbonic acid, and the generation of a quantity of water, even more than that of the alcohol itſelf. In the latter circumſtance, the combuſtion of alcohol agrees with that of hydrogen, in the former it differs.

The mere production of water was exhibited by Lavoiſier in the following method. A ſpirit lamp, drawing air freely from the atmoſphere, was ſet within a ſmall chimney, which conducted the heated vapour into a ſpiral worm tube, kept cool by being ſurrounded with cold water, as in common diſtillation. The water produced by the burned alcohol was condenſed in the warm tube, and being collected and accurately meaſured, was found to exceed the quantity of ſpirit conſumed by about one ſixteenth; ſixteen ounces of ſpirit having generated about ſeventeen ounces of water. The carbonic acid produced at the ſame time, was not noted.

The experiments of Dr. Prieſtley alſo throw much light on the compoſition of alcohol. By taking the electric ſpark in this fluid, he obtained from it a conſiderable quantity of highly inflammable air.[i] But the moſt curious experiments were made by paſſing the vapour of heated alcohol through tubes of earth or copper made red hot.[k] When earthen tubes were uſed, the ſpirit was moſtly converted into inflammable air, the tubes themſelves remaining unaltered. But it was otherwiſe with the copper tubes, for, as the author obſerves, "the vapour of "the ſpirit of wine had no ſooner entered the "hot copper tube, than I perfectly aſtoniſhed "at the rapid production of air. It reſembled "the blowing of a pair of bellows. But I had "not uſed four ounces of the ſpirit of wine, "before I very unexpectedly found that the "tube was perforated in ſeveral places, and "preſently afterwards was ſo far deſtroyed, "that in attempting to remove it from the fire, "it actually fell in pieces. The inſide was full "of a black ſooty matter reſembling lamp-"black."

Not only was much of this ſooty matter detained by union with the copper, but a very large quantity eſcaped in the form of a black incoercible vapour, which preſently filled all the veſſels that were ſet to receive it, and could not even be condenſed by paſſing through water. The copper, rendered black and friable by this proceſs, the author terms *charcoal of copper*. The other metals that were tried did not anſwer ſo well as copper in decompoſing the alcohol.

Dr. Prieſtley's valuable experiments were repeated by Dr. Van Marum, and the other aſſociated chemiſts of the Teylerian Inſtitution of Amſterdam. Wedgewood's porcelain tubes were employed, which were prevented from cracking on the ſudden application of heat, by being firſt incloſed in iron tubes the length of the furnace. One extremity of the earthen tube united with the retort in which the alcohol was boiled, the other terminated in a metallic ſerpentine, or ſpiral tube, immerſed in water, to receive and condenſe the vapours which might be generated. Copper wire was introduced within the earthen tube, and when made red hot, the vapour of the boiling ſpirit was ſent through. The reſults of the different experiments were the ſame eſſentially with thoſe of Dr. Prieſtley, that is, the alcohol was decompoſed, and furniſhed much carbonaceous matter, which united with the copper, converting it to a friable carburet. Dr. Van Marum alſo found that a very large quantity of hydrogen gas was given out in the proceſs, the more abundant in proportion to the intenſity of heat in the tube. Three ounces of alcohol in one experiment, gave ten cubic feet of carburetted

[i] Experiments on Natural Philoſophy. Vol. I. [k] Ditto Vol. III.

hydrogen gas, and 180 grains of charcoal, united with the copper; but the refults of the other experiments differed as much in the proportion of this matter as that of the hydrogen.

Thefe experiments, though highly curious, are too variable, and offer too complicated refults, to throw much light on the actual proportion of the conftituent parts of alcohol: for, on the one hand, the charcoal produced does not equal the quantity eftimated to exift in fpirit by Lavoifier's experiment; and on the other, the quantity of the hydrogen gas given out is fo great, and its nature and proportion of diffolved carbon probably fo various, in different parts of the procefs, that no calculation can be made from it with fufficient accuracy.

We can therefore at prefent only infer from all that has been done on the compofition of alcohol, that it is compofed of fome hydrogen and much carbon, probably in intimate union with each other, alfo joined to a certain proportion of water, varying according to the fpecific gravity of the fpirit, but which even in the moft concentrated alcohol which we are able to produce by art, forms, perhaps, full half its weight, and appears to be a neceffary conftituent.

With the large proportion of carbon which alcohol alfo contains, it is not eafy to explain why, during its combuftion, contrary to the habitude of moft other vegetable matter, every part capable of burning, is at once moft completely oxygenized in the higheft degree; and why, with fo large a proportion of water of compofition, it is found to be, when pure, fo highly combuftible.

The mutual action between alcohol and various faline fubftances, deferves notice.

The fixed alkalies, when cauftic, are foluble in this fpirit, as we have already mentioned, but the carbonated alkalies have no other action on it than to deprive it of its redundant water. When cauftic alkali is digefted with alcohol, in a fhort time the fpirit becomes of a yellowifh, and afterwards of a high red brown colour, as it takes up the alkali. This folution is the *Tincture of Tartar* of Van Helmont, now difufed in medicine. The folution may be made either by adding the cauftic alkali alone to the fpirit, or by mixing two parts of flacked lime, and one of carbonated potafh, with eight of alcohol,[1] and frequently fhaking the mixture till the whole is diffolved. The ftrongeft alcohol diffolves about 0.187 of its weight of dry cauftic potafh, when heated. The fpirit however is decompofed, partially or entirely according to the time of digeftion, by this mixture.

The hot alkaline folution depofits on cooling, though kept in a clofe veffel, many rhomboidal or fpicular cryftals, the nature of which was not at firft well underftood, but which are now fully proved to be the cryftallized, or fully faturated carbonated potafh. The fource of the carbonic acid in this cafe, muft be the alcohol, which therefore muft have undergone decompofition. Pelletier[m] kept a pound of alcohol in digeftion with four ounces of cauftic potafh for two years, in a matrafs ftopped at the mouth with parchment. At the end of this time no fpirituous principle remained in the liquor, which was of a deep red, and had depofited a large quantity of cryftals of potafh fully faturated with carbonic acid.

If the alcohol is diftilled off the recent mixture with cauftic alkali, it rifes extremely pure and dephlegmated, but at the fame time it undergoes much lofs in quantity of actual fpirit, and if this be repeatedly abftracted by diftillation, the fpirit is loft, being converted partly into carbonic acid, and alfo into the acetous, both of which appear united with the alkali into the carbonat and acetite of potafh. Lime decompofes the fpirit by diftillation as potafh does, much water is feparated, the fpirituous is exchanged for a naufeous fmell and tafte, and the lime becomes carbonated. Lime water fimply depofits its lime when mixed with pure alcohol, and the earth is in a cauftic ftate.

Pure ammonia readily diffolves in alcohol, and the carbonated volatile alkali to a certain degree, efpecially when united by means of diftillation. However, alcohol added to a faturated folution of carbonated ammonia in water, feparates the greateft part of the falt in a confufedly cryftalline mafs called formerly *Offa Alba Helmontii*. (See AMMONIA).

The ftronger acids act in a very remarkable degree upon alcohol, producing by the mixture that fragrant, light, inflammable liquid called ETHER; and alfo a quantity of carbonic, oxalic, and acetic acids, all arifing from the mutual decompofition of the fpirit and acid. We fhall defcribe, under the article *Ether*, the various proceffes for obtaining it, and fhall here only mention a few of the facts which throw light on the compofition of ardent fpirit.

Scheele obferved, that when fpirit of wine and fulphuric acid are diftilled together, after the ethereous product is given out, a quantity of acetous acid rifes by continuing the heat, which is mixed with the fulphureous acid gas.

But the nitric acid acts with more energy

[1] Meyer. [m] Mem. & Obf. de Chimie.

in decompoſing alcohol. Bergman mentions that the reſidue left after diſtilling twenty-four parts of nitrous acid and eight of alcohol, if re-diſſolved and cryſtallized, gives three parts of cryſtals of oxalic acid. The following experiment will ſhew the decompoſition of ſpirit. On one pound of ſtrong alcohol put into a long necked retort, and connected with the pneumatic apparatus, add four ounces of ſtrong nitrous acid, with great caution, at repeated times, and apply a very gentle heat. Nitrous ether, nitrous gas, and carbonic acid are at firſt given out, which laſt may be abſorbed by lime water, and rendered ſenſible. When no more gas is given out, add three ounces more of the nitrous acid to the reſidue, which, again diſtilled, gives the ſame products as at firſt. Then by ſlow evaporation of the liquor left in the retort, cryſtals of oxalic acid will be obtained. If the quantity of nitrous acid be conſiderable, or the boiling of the materials briſk, much acetous acid is alſo obtained, which is found mixed with the diſtilled nitrous ether.

Under the article *Acetous Acid*, the operation of the oxy-muriatic acid upon the reſidue of the diſtillation of nitrous ether, is alſo deſcribed, and the production of the acetous and oxalic acids.

The preparation of Howard's *fulminating* MERCURY alſo ſhews, in a ſtriking manner, the generation of oxalic acid from alcohol, by the nitric acid, this ſingular compound being an oxalat of mercury, prepared by digeſting alcohol with the nitrat of that metal.

The weaker acids, ſuch as the oxalic, gallic, tartaric, and the like, when added to alcohol, are merely diſſolved by the ſpirit, but do not appear to decompoſe it, except very imperfectly and with conſiderable difficulty. Many of them are cryſtallizable from the hot alcoholic ſolution by cooling, ſuch as the gallic and oxalic acids. The latter requires $2\frac{1}{2}$ times its weight of alcohol in a cool temperature for ſolution, but only about $1\frac{1}{4}$ of boiling ſpirit.

The alkaline, earthy and metallic neutral ſalts, are very variouſly affected by alcohol. Some it diſſolves copiouſly, others ſparingly, and thoſe on which it has little or no ſolvent power, it precipitates from their watery ſolution. The ſolubility of ſalts in alcohol is a ſubject of conſiderable intereſt to chemical analyſis, and ſeveral ſeries of experiments have been made, ſome of which we ſhall notice.

Macquer[n] examined with great care the ſolubility of the ſulphats, nitrats and muriats of potaſh, ſoda, ammonia, lime, ſilver, copper, iron, and mercury. To prevent inaccuracy with regard to the variable quantity of water of cryſtallization, he dried them all in a heat ſufficient to expel this water. The alcohol was the ſame in all, being of the ſpecific gravity of .8437, at 54.5 Fahr. equal to .840° at 60°. The ſalts were put ſeparately in a matraſs, half an ounce (French), or two hundred and eighty-eight grains of the alcohol, was poured on them, the veſſel was corked and heated till the ſpirit began to boil, after which it was immediately filtered while hot, and firſt ſuffered to cool gradually, to aſcertain whether the ſalt would depoſit by cryſtallization, and next evaporated entirely and the total reſidue collected and weighed. A ſecond comparative experiment was made on each, in which the ſpirit was burnt off, inſtead of being evaporated, that the appearance of the flame might be noticed.

The ſulphats were all found abſolutely or very nearly inſoluble. It is remarkable that the dried ſulphat of copper gave no green colour to the flame of the ſpirit, though when with its water of cryſtallization this colour is very apparent.

Of the nitrats, four grains of nitre were diſſolved in the half ounce (or two hundred and eighty-eight grains) of alcohol, part of which cryſtallized on cooling. The flame of this ſolution was much larger, yellower and brighter than that of common alcohol.

Of the nitrated ſoda fifteen grains were diſſolved. The flame was like the laſt, but more intenſe. Nitrated ammonia diſſolved in very conſiderable quantity; one hundred and eight grains were found, after evaporation, of the ſpirit, which acquired ſomewhat of an etherial ſmell by the boiling. The flame was white, luminous, and ſomewhat fuliginous.

The alcohol diſſolved its own weight of nitrated lime, and the ſolution was thick like oil. None of the ſalt was depoſited by cooling. The flame was large, red, and luminous, and the ſpirit burned with a crackling noiſe.

Eighty-four grains of nitrated ſilver were diſſolved in the alcohol, which, as before, acquired ſomething of the ſmell of ether. Nitrated mercury was ſcarcely ſoluble. Of nitrated copper forty-eight grains were diſſolved; the flame beautifully bright and of a deep green.

Of the muriats, common ſalt was ſcarcely, if at all ſoluble in the ſpirit. Of muriated ammonia, twenty-four grains were diſſolved by the half-ounce of ſpirit; of muriated lime, two

[n] Mem. Ac. Turin, tom. 3.

hundred and eighty-eight grains, or equal to the weight of the ſpirit, and the flame preſented the ſame appearances with the nitrated lime. Luna cornea, or muriated ſilver, was entirely inſoluble; of corroſive ſublimate, two hundred and four grains were diſſolved, much of which cryſtallized on cooling, and the flame was large, yellow, and decrepitating; of muriated iron, thirty-ſix grains, the flame white and brilliant, and towards the end, ſparkling; of muriated copper, forty-eight grains, the flame beautifully green, accompanied with white and red ſparks.

The above experiments appear to have been made with great care, and are therefore, to a conſiderable degree, accurate; but however, ſome unavoidable ſources of error may be detected, which in ſome degree affect the reſults. In boiling the alcohol over the ſalt, ſome part of it muſt evaporate; in filtering the ſolution, a portion muſt remain in the pores of the filter; and in drying the ſalts, ſome of thoſe with a metallic baſe would be liable to be, in ſome degree, decompoſed. The experiments are notwithſtanding valuable, and deſerve notice.

Lavoiſier made a ſeries of experiments on the ſame ſubject, uſing alcohol, mixed with water, in eight different proportions. He found that the pure ſpirit did not diſſolve either carbonated ſoda or ſulphated ſoda, or ſulphated magneſia, or common ſalt, or even muriated magneſia. When mixed with half its weight of water, it diſſolved a conſiderable quantity of common ſalt, but ſulphat of ſoda was not diſſolved in any mixture in which the quantity of ſpirit exceeded that of water, without boiling, and on cooling the whole again cryſtallized.

Wenzel undertook a ſeries of experiments on the ſame ſubject, of which the following is a part of the reſult.[o] The quantity of ſpirit uſed in each trial was two hundred and forty grains; its ſpecific gravity, however, is not mentioned, but probably it was ſomewhere between .825 and .840°. The heat 180°, or about the boiling point of the ſpirit.

	Grains.
Nitrat of potaſh	5
——— ſoda	23
——— ammonia	214
——— lime	288
——— magneſia	694
——— alumine	240
Muriat of potaſh	5
——— ammonia	17
——— lime	288
——— magneſia	1313
Fluat of ammonia	1
——— alumine	1
Borat of ammonia	1
Tartrite of potaſh	1
Cream of tartar	7
Tartrite of ammonia	7
——— alumine	7
Oxalat of alumine	7
Acidulous oxalat of potaſh	7

Laſtly, we ſhall give the very accurate experiments of Mr. Kirwan[p] on this ſubject, which is of ſo much importance in the difficult buſineſs of the chemical analyſis of ſaline ſubſtances.

Mr. K. employed ſpirit of five different degrees of ſtrength, namely, .817, or the moſt highly concentrated; .834 (or what, according to Mr. Gilpin's tables, would be produced by mixing one hundred grains of the pureſt ſpirit of ſimple diſtillation, viz. .825, with about 5 grains of water;) .848 (equal to one hundred grains of the above ſpirit, with about 11 grains of water); .872 (equal to one hundred grains of the ſpirit, with about 27 of water); and .900, equal to one hundred of the ſpirit with about 59 grains of water. The temperature was never higher than 80°, the time of digeſtion about three days, and the ſalts were deprived of their water of cryſtallization.

[o] Gren. Syſt. Hand.

[p] On Mineral Waters.

	100 grains of Alcohol at				
	.900	.872	.848	.834	.817
Sulphat of ſoda	0	0	0	0	0
——— magneſia	1	1	0	0	0
Nitrat of potaſh	2.76	1	0	0	0
——— ſoda	10.5	6.		0.28	0
Muriat of potaſh	4.62	1.66		0.38	0
——— ſoda	5.8	3.67		0.5	
——— ammonia	7.5	4.75		1.5	
——— magneſia, dried at 120°	21.25		23.75	36.25	50
——— barytes	1.		.29	.185	.09
——— ——— cryſtallized	1.56		.43	.32	.06
Acetite of lime	2.4		4.12	4.75	4.88

A ſubject of equal importance in chemical analyſis, with the ſolubility of certain ſaline ſubſtances, is the precipitability of others from their aqueous ſolution on addition of alcohol. This takes place to a greater or leſs degree when ſpirit is added to a watery ſolution of any ſalt inſoluble, or nearly ſo, in alcohol. Thus, by way of experiment, if ſome alcohol is added to a moderately ſtrong ſolution of ſulphated ſoda, in water, the ſpirit unites with the water, and precipitates the ſalt, which is ſeen to fall down immediately in the form of a white granular maſs of irregular minute cryſtals.

There are ſome ſalts entirely ſeparable from their water of ſolution by this method, which, when properly applied, is of great utility in analyſes of water, particularly of mineral waters, where the foreign ingredients are generally compoſed of ſalts ſoluble and inſoluble in alcohol. We are again indebted to Mr. Kirwan's[q] accurate experiments for much information on this ſubject, directed particularly to aſcertain the leaſt proportions of the ſalt to the water, on which the ſpirit begins to exert its precipitating power, and the loweſt ſpecific gravity of the ſpirit requiſite to produce this effect, as in all caſes the precipitation takes place the ſooneſt with the pureſt alcohol and the ſtrongeſt ſaline ſolution. A gentle heat alſo much aſſiſts this ſeparation.

The ſpirit muſt be at leaſt equal in bulk to the ſaline ſolution, and ſometimes twice or thrice the quantity is required.

The reſult of Mr. Kirwan's experiments were, that ſelenite may be compleatly precipitated from water that contains it in the proportion of $\frac{1}{1000}$ by any ſpirit whoſe ſpecific gravity is below .850. The ſame precipitation takes place with regard to the alkaline ſulphats of equal ſtrength, but theſe require a ſpirit of .817, and a longer time; ſo that ſulphat of lime may be ſeparated from the ſulphats of potaſh and ſoda, ſimply by a properly managed addition of alcohol.

Alum muſt be in greater proportion than $\frac{1}{1000}$ to be precipitated by ſpirit of .834, unleſs triple the volume of the ſolution be added, and heat be applied.

Sulphat of magneſia muſt be in greater proportion than $\frac{1}{240}$ to be immediately precipitated by alcohol of .834.

Alcohol digeſted for ſome days on Phosphorus, diſſolves a ſmall quantity of it, ſufficient to render the ſolution luminous in the dark, when ſpread on a warm ſurface (the face or hands for example) which evaporates the ſpirit. The quantity of phoſphorus, though enough to ſhine in the dark, is too minute to do the leaſt injury to the ſkin. The alcoholic ſolution dropped ſlowly into water, in a dark place, exhibits elegant waves of light, at the moment that the two liquids touch each other.

Sulphur is not acted on by alcohol by ſimple digeſtion either hot or cold, but the two may be made to unite by the medium of diſtillation. (See Sulphur.)

The habitudes of alcohol with many of the moſt important vegetable ſubſtances, are highly intereſting.

Moſt of the pure Resins are ſoluble without difficulty in this fluid. The Gum-Resins, however, are only partially ſoluble in ſtrong alcohol, as it acts only on the truly reſinous part; but a dilute ſpirit will hold the whole in perfect ſolution. If water be added to a ſpirituous ſolution of a pure reſin, guaiacum for example, the water and ſpirit unite, and moſt of the reſin is precipitated in the form of a flaky curd. This affords one method of obtaining theſe reſins in

[q] Min. Waters, p. 266.

great purity, in a ſolid or rather pulverulent form. A ſolution of a reſin, or gum-reſin, is called, particularly in pharmacy, a *Tincture*. If a ſaturated reſinous tincture is ſlowly heated, the ſpirit evaporates, and leaves the reſin at laſt, either as a ſoft tenacious paſte, or, if further dried, concreted into a very hard brittle maſs, retaining in a high degree, all the properties, ſenſible and medicinal, of the original ſubſtance. This is termed a *Reſinous* EXTRACT, and the proceſs is of uſe in concentrating into a ſmall bulk the truly medicinal part of entire roots, or other groſs parts of plants. The reſin thus obtained from a tincture of jalap root is an example.

A few ſubſtances uſually claſſed under the head of Reſins, are however with great difficulty ſoluble in alcohol. Gum copal and amber are of this kind, but theſe partake rather more of the nature of fat oils.

Camphor diſſolves with great facility in about four times its weight of alcohol of moderate ſtrength. An addition of water ſeparates the greater part of the camphor, the ſame as with the reſinous ſolutions.

All the eſſential oils mix uniformly with alcohol, and are diſſolved in it the more copiouſly in proportion to the ſtrength of the ſpirit. This affords an eaſy and elegant method of giving flavour to the various ſpirits uſed for the table, and alſo of extracting the perfumed ſcents of flowers and plants for the toilet. See the articles SPIRITS *Diſtilled*, and OIL *Eſſential*.

Alcohol, reſins, and eſſential oils, form the ingredients of a great variety of VARNISHES.

None of the fat oils, while in their original ſtate, are ſoluble in this menſtruum, which only extracts from them their colour and ſmell. But if altered, either by fire, ſo as to become *empyreumatic*, or by ſome of thoſe proceſſes which render them *concrete* and *drying*, or, if attenuated by repeated diſtillation, as in the caſe of the rectified *animal oil of Dippel*, or laſtly, if previouſly united to an alkali into a *ſoap*, they become to a greater or leſs degree ſoluble in ſpirit.

Alcohol diſſolves about one-third of its weight of good ſoap, if not overloaded with oil. The ſolution is perfectly limpid, and is of ſome uſe in the analyſis of mineral waters, as a teſt for earthy ſalts, by which it is curdled.

The green colouring matter of the leaves and other parts of vegetables, is taken up by alcohol, according to the accurate obſervations of Mr. Sennebier. The green tincture is equally well prepared from the green pulp extracted from theſe parts by water and digeſted in alcohol. The ſun's light turns the colour of the tincture to a yellow. Water, acids, and alkalies, render it turbid.

Sugar diſſolves in about three times its weight of alcohol of moderate ſtrength, and as the ſpirit has ſcarcely any action on the mucilage with which ſugar is mixed in the native ſweet juices of vegetables, this liquid forms a uſeful medium for ſeparating the pure ſaccharine part; too expenſive indeed for the purpoſes of manufacture, but which may be applied with great advantage in analyſis. For example, to ſeparate the ſugar from carrots, dry the root, reduce it to a coarſe powder or paſte, digeſt it in a heat brought ſlowly to boiling, with about its own weight of ſtrong alcohol; ſtrain the ſpirit, and ſeparate the laſt portions by ſtrong preſſure, and ſlowly evaporate the ſpirituous ſolution to a ſmall bulk, after which let it ſtand in a warm place till dry. The reſidue in moſt caſes after ſuch an analyſis, is little elſe than the purely ſaccharine part. Moſt of it may be obtained cryſtallized, by a much ſlower and nearly ſpontaneous evaporation.

Not many animal ſubſtances are acted on by alcohol in any great degree. Thoſe which it does diſſolve are the animal reſinous matters, ſuch as muſk, caſtor &c. ſpermaceti, adipocire, wax, and ſome of the altered oils; but in moſt caſes the action of alcohol on animal ſubſtances is in a great meaſure ſimilar to that on vegetable ſubſtances, reſembling them in chemical nature.

In ſome caſes alcohol acts only when dilute, and here it ſeems rather not to impede the action of the water with which it is mixed. So iſinglaſs or other animal jelly will diſſolve in common ardent ſpirit, and this ſolution ſpread upon thin cloth or ſilk, evaporates ſpeedily, leaving a fine coating of the jelly. This is the baſis of the well-known *Court* or *Sticking Plaſter*. It generally happens that where alcohol does not diſſolve, it coagulates, or ſeparates from the watery ſolution. Thus it coagulates albumen from its natural ſolutions in the ſerum of blood, milk, and ſometimes animal lymph. Milk curdled by ardent ſpirit, forms a well-known and agreeable preparation for the table.

If animal fibre or fleſh is immerſed in alcohol, its red colour, which depends on the blood remaining in the blood-veſſels, is ſlowly extracted, and tinges the ſpirit; at the ſame time that the fleſh itſelf becomes ſhrivelled, much hardened, greyiſh white, and abſolutely incapable of putrefaction or further change.

Alcohol therefore is a moſt powerful anti-

ſeptic, and it exerts this power upon every ſubſtance, animal or vegetable, capable of fermentation or ſpontaneous change.

The uſes of alcohol in its various forms are very numerous and important. As the intoxicating baſis of all vinous or ſpirituous liquors, it is only employed in the intermediate ſtate of diſtilled ſpirits. In the arts it forms a moſt important ingredient in many varniſhes; in pharmacy it is the liquid component of tinctures and other preparations; it preſerves from corruption all the wet preparations of the anatomiſt; and to the chemiſt it is an invaluable agent, operating on a great number of ſubſtances for which no other proper ſolvent could be found, and at the ſame time altering their nature ſo little as to exhibit them nearly in their original ſtate when expelled by evaporation. Many other leſs important uſes might be mentioned, ſuch as in filling thermometers, and another of great advantage in the nicer chemical operations, is that, as a combuſtible, it affords a gentle ſteady flame, unfouled by ſmoke or any vapour which can obſcure the ſight of the proceſs which is going on in the veſſel ſo heated.

Alcohol is ſeldom adulterated with any foreign matter. It ſhould be neither acid nor alkaline, and the methods for aſcertaining the degree of its dilution with water have been already mentioned.

It is of advantage for the purpoſe of the laboratory, to keep it of ſeveral degrees of ſtrength for its different uſes. Of theſe the ſpecific gravity of .825 at 60° which is a very convenient ſtandard for compariſon, ſhould be one; a higher degree of dephlegmation by means of potaſh, another; and two or three mixtures lower than the ſtandard, ſuch as .846 which is nearly the common rectified ſpirit of the ſhops, and one or two of inferior ſtrength.

ALCOHOL *Aceti*, a term given by Weſtendorf to his radical or concentrated vinegar. See Acetous *Acid*.

ALEMBIC, an article of chemical apparatus. See the *Appendix*.

ALEMBORTH *Salt*, a term nearly antiquated, employed to expreſs the very ſoluble triple ſalt formed by uniting muriated ammonia to corroſive mercurial muriat. See Mercury.

ALGAROTH *Powder*, is a white oxyd of antimony, prepared by dropping the liquid butter of antimony into water. It is by ſome uſed in medicine, as the baſis of the emetic tartar. See Antimony.

ALKALI.

ALKALINE EARTH. The claſs of alkalies is amongſt the moſt antient in chemical ſcience, and one which has ſtood its ground through all the changes occaſioned by modern diſcoveries, though with ſome modification.

The original application of the term *alkali* (which is of Arabian origin) was to expreſs the acrid ſaline reſidue left in the aſhes of the plant *kali*, after its combuſtion in open air. This was alſo very early known to the Greeks and Romans; by the latter termed, *lixivial*, which term is ſtill retained, *lixivium*, or *ley*, meaning properly the ſoluble ſalt extracted out of vegetable aſhes by the addition of water. From the circumſtance of the aſhes being the fixed or unvolatilized part of the plant, the reſt having been diſſipated by the combuſtion, the lixiviary ſalt was alſo called *fixed* alkali, a term ſtill in univerſal uſe. The proper fixed alkalies are of two kinds, the vegetable or *potaſh*, and the mineral or *ſoda*; the latter is found often native in immenſe quantities being the baſis of rock ſalt, and is alſo the principal ſaline reſidue of many plants growing on the ſea ſhore; and the former is contained in, and almoſt entirely procured from, the aſhes of vegetables in general, not growing contiguous to the ſea. Under the articles Potash and Soda, and Carbonat of *Potaſh* and *Soda*, theſe moſt important Salts are fully deſcribed.

Again, as the volatile ammoniacal ſalt procurable from moſt animal matter (alſo of great antiquity) was found to agree with the other alkalies in taſte, and in many chemical properties, though not in fixity, this ammoniacal ſalt was alſo termed an alkali, but *volatile*, in oppoſition to the two former, which remain unaltered in very conſiderable heat, and are therefore, comparatively, *fixed*. The volatile alkali is deſcribed under the article Ammonia.

Of late years, ſome of the earths (eſpecially barytes and ſtrontian, which were unknown to antiquity) having been found to poſſeſs alkaline properties in no ambiguous degree, theſe have been by ſome chemiſts abſolutely aſſociated with the alkalies; by others have received the term *alkaline earths*, to expreſs this reſemblance which in the two above mentioned almoſt amounts to identity of properties; but in the two others, lime and magneſia, the agreement is only partial.

As it is but of little conſequence which arrangement be adopted, provided an uniformity be obſerved, we have throughout the preſent work reſtricted the term *alkali*, to the three antient ſalts of that name; the two *fixed*, potaſh and ſoda, and the *volatile*, ammonia. Under

the appellation *alkaline earth*, we include the following, Barytes, Strontian, Lime, and Magnesia.

We shall now enumerate the properties usually described as belonging to alkalies, distinguishing how far they are possessed by the three salts and the four earths above enumerated.

The taste of an alkali is acrid, burning, and nauseous. It acts with so much energy and rapidity on the tongue, as to destroy, if concentrated, the skin of the part which it touches, and hence its extreme causticity. The three alkalies possess this in the highest degree, being more rapidly soluble than the earths, and of the latter only barytes, strontian, and lime, exhibit this corrosive taste, magnesia being absolutely insipid.

All the alkalies, except ammonia, are without smell, or nearly so, a particular urinous odour however arises during the solution with heat, of the other alkalies and earths, magnesia excepted.

Ammonia (whose natural state when uncombined, is that of a gas) magnesia, and probably lime, are incapable of crystallization, the other alkalies and alkaline earths are crystallizable.

Only the volatile alkali has been decomposed. The others have often been suspected to be also compound, and with some probability, but they have hitherto eluded the attempts of chemists to decompose them.

Ammonia alone is volatilized by the application of any degree less than a red heat; when fully red, or at a heat about that of melting copper, the fixed alkalies begin to be dissipated in dense vapours, but the alkaline earths resist any but the extremest degree of heat which has ever been applied.

The alkalies are extremely soluble in water, barytes and strontian in considerable quantity, lime, sparingly; magnesia scarcely at all.

They possess the strongest affinity for acids of all other bodies, uniting with them generally to such a degree as to produce perfect neutralization, or such a state of union, that the characteristic properties of both acid and alkali are lost, and new ones acquired. Most of the combinations with acids are considerably soluble in water, and all crystallizable with more or less ease.

The comparative force of affinity for the individual acids possessed by the alkalies and the alkaline earths, is not uniformly the same, but generally one or two of the earths stand the highest in force. The affinity of them all for acids is superior to that of the metallic oxyds, and hence they decompose metallic solutions.

They all have their peculiar alkaline properties highly modified and lessened, but not entirely taken away, by union with carbonic acid. Hence the states of *mild* and *caustic*, the former expressing union with this acid; the latter, the contrary; which obtains in all these substances, though in magnesia alone the difference is scarcely perceptible as it regards the sensible properties.

They all unite with sulphur, forming compounds soluble in water, of a peculiar foetid smell, tarnishing the white metals, called sulphurets or hydro-sulphurets, according to circumstances.

They all unite with the fixed oils and animal fats, either into a true soap, or into a saponaceous compound. The fixed alkalies unite more perfectly with the oils, and the alkaline are the only true soaps, being soluble in water. The earthy mixtures with oil are indeed strongly combined, but are insoluble in water. Barytes will combine directly with oils, as M. Vauquelin has found,[a] and when heated with animal matter, will cause it to give out a large quantity of ammonia, and will reduce it to a kind of saponaceous soluble mass.

When in fusion in a red heat (from which of course the volatile alkali is excepted) they dissolve silex into that beautiful transparent compound called *glass*. This property of vitrification is the strongest in the alkalies, but has been found by M. Vauquelin to be very powerful in strontian and barytes.

With the exception of magnesia, they all powerfully corrode the soft parts of vegetables, and especially animals. Bulk for bulk, the fixed alkalies are by far the most powerful and active in this respect.

Lastly, they all produce certain changes on some vegetable colours, and this test is perhaps the most striking of all above enumerated, since it is possessed by all without exception, though with some variety. The blue colours of many plants are changed by them to green, of which the syrup or tincture of violets, affords a ready instance; many of the reds, such as that of logwood and litmus, are changed into violet; and the yellow of a great many plants, such as turmeric, rhubarb, or liquorice root, is changed to a brown, or dirty brick red.

The latter change seems to be confined to the alkalies when both are carbonated, so that

[a] An. Chem. Tom. 29.

the change of turmeric-yellow into red will diſtinguiſh the preſence of a carbonated alkali from that of an alkaline earth, held in ſolution by an exceſs of carbonic acid. But when pure or cauſtic, the change is the ſame in both. The power of all theſe ſubſtances over the vegetable colours is very great in proportion to the quantity uſed, and it ſhould be remarked, that in this inſtance alſo, acids and alkalies, or alkaline earths, are in direct oppoſition to each other, the acid reſtoring the colour to its original ſtate, after it has been changed by the alkali, and vice verſa. Hence a ſingle coloured vegetable may be made a very delicate teſt for both acids and alkalies; litmus, for example, previouſly reddened by acids, will be changed into purple by alkalies, and purpled litmus will detect an acid by becoming red.

It appears therefore that there is ſcarcely a ſingle characteriſtic except the change of certain colours, that will apply equally to all the alkalies and akaline earths, but yet the general reſemblance is ſo great as to juſtify this claſſification. Magneſia alone has the leaſt claim to the title of an alkaline earth, and yet its affinity to acids is ſtrong, and its power of changing ſome of the vegetable colours is very conſiderable.

ALKALINE *Air*. The term given by the diſcoverer, Dr. Prieſtley, to the volatile alkali in its pure or gaſeous form. See AMMONIA.

ALKANNET. *Oreanette*, Fr. A colouring root, cultivated in many parts of the ſouth of Europe, and brought in ſmall quantities from the Levant. The plant grows to about a foot in height. The root, which is the part uſed as a dye, is as big as the thumb, red without and white in its inner part. The outer red portion is alone uſed for colouring. It grows in abundance in Languedoc, in dry ſandy ſoils. The root is dried in the ſun, and undergoes no other preparation. When good it is ſomewhat elaſtic though dry, of a deep red without, and ſhould ſtain the finger nail freely when rubbed upon it, wet or dry.

Alkannet root imparts its deep red colour very freely to ſpirit of wine, the eſſential and fixed oils, wax, fat, and any other unctuous ſubſtance, and hence it is of conſiderable uſe in making ſome of the coloured oils or varniſhes. To give a red colour to wax, for example, melt it, and infuſe ſmall pieces of the root in it for a few minutes, till it has acquired the requiſite colour.

ALLOY. *Alliage*, Fr. *Legiren*, *Metallverſetſung*, Germ.

A maſs formed by the mixture of any two or more metallic bodies, in which the different conſtituent parts cannot be diſtinguiſhed from each other by their external characters, is an alloy. In this definition no diſtinction is made between mere intimate mechanical mixtures, and proper chemical compounds, becauſe we are not as yet poſſeſſed of ſufficiently accurate experiments, to aſcertain which ſpecies belong to the former, and which to the latter claſs. The mixed metals into which mercury enters, are called Amalgams, and will be treated of at large under the article Mercury, as they are poſſeſſed of a number of curious and peculiar properties: in their general characters however they reſemble the other metallic compounds, and therefore the obſervations in this article are equally applicable to each.

It is much to be regretted that a ſubject of ſuch great importance both practical and theoretical, ſhould have been ſo little attended to by modern chemiſts. The experiments of Gellert, Homberg, and Kraaft, inaccurate as they were, ſtill continue to be our principal authorities, corrected and enlarged indeed on ſome points by Lewis, Darcet, Marggraf, and Guyton. But of all modern chemiſts, Mr. Hatchett is the one to whom this branch of the ſcience is the moſt indebted: by ſhewing the peculiar difficulties which attend the inveſtigation of this intereſting ſubject, he has introduced conſiderable ſcepticiſm with regard to what has already been done; and the removal of ancient error is the firſt ſtep towards the eſtabliſhment of modern truth.

Almoſt every metal that is met with in commerce, contains a ſmall variable proportion of ſome other metal, and therefore, ſtrictly ſpeaking, they are all alloys; thus lead contains ſilver; tin, arſenic; copper, iron; but after the uſual proceſſes of refining are gone through, the quantity which each holds of any other metal is ſo ſmall, that its properties are not perceptibly altered by ſuch admixture. A metallic maſs therefore is ſcarcely conſidered as an alloy except the characters of the prevalent metal are obviouſly modified; in the ſame manner as the oil of vitriol of the ſhops acts the part and bears the name of ſulphuric acid, notwithſtanding a minute portion of potaſh with which it is combined.

Alloys are prepared either by melting the ingredients ſeparately and pouring them together when they are liquid; or by fuſing them all down together in the ſame crucible. When the metals employed are of different degrees of fuſibility, and eſpecially when the one that is

the eaſieſt fuſible is alſo very inflammable, the firſt method is had recourſe to; as when copper and zinc or copper and tin are to be combined; but the latter is practiſed in thoſe caſes where the materials are either nearly of the ſame degree of fuſibility, or at leaſt where the temperature required for melting the leaſt fuſible, is not ſufficient to volatilize that which is the moſt ſo. In order to prevent oxydation, the crucible ought to be lined with charcoal, and a quantity of decrepitated ſalt ſhould be ſtrewed over the top of the ingredients, which melting at a very low red heat, will float on the ſurface of the metal, and thus exclude the contact of the air. By taking theſe precautions, a lower and longer continued heat may be advantageouſly ſubſtituted for a ſhorter and more violent one, the ingredients will be mingled more perfectly, and the loſs and conſequent inaccuracy when experimenting on the moſt inflammable metals, will in a great meaſure be avoided. As ſoon as the maſs is liquefied, it will be of advantage to ſtir it repeatedly, to prevent the ingredients from ſeparating according to their reſpective ſpecific gravity, before they have had an opportunity of combining together; for this purpoſe a charred ſtick, or rod of baked clay, is to be preferred to one of iron, as this laſt would in many caſes be acted upon by the melted metal, and ſpoil the proceſs. The alloy ſhould alſo be poured alternately from one red hot crucible into another, and back again, to inſure the intimate mixture of the ingredients. Theſe are by no means uſeleſs precautions, for where one of the metals is of conſiderably greater denſity than the other, it requires particular care to make the quality of the alloy equal throughout the whole of the maſs. Schlutter relates,[a] that twenty pounds weight of ſilver, containing about a 56th part of gold, was melted in a crucible, and poured into cold water to be granulated: ſamples from the top, middle, and bottom of the maſs were then aſſayed, and were found all to differ in their proportions of gold. In like manner Mr. Hatchett obſerved,[b] that gold made ſtandard, with the uſual precautions, by ſilver, copper, lead, antimony, &c. and then caſt into vertical bars, was by no means diſtributed equally, but that the top of each bar, (being compoſed of the portion of alloy which occupied the *bottom* of the crucible) was both purer and of greater ſpecific gravity than the lower end of the bar.

It is a matter of conſiderable importance to aſcertain whether alloys are mere mixtures or proper chemical compounds: in moſt inſtances there ſeems to be little or no doubt of the latter being the caſe, and perhaps all the ſuppoſed examples of the contrary may be looked upon as inſtances of the ſuperſaturation of one of the ingredients by the other.

The rule that is laid down in moſt chemical books for aſcertaining whether a maſs of metal is an alloy or a ſimple mixture, is to fuſe it with as little heat as poſſible, and to keep it in this ſtate till its component parts ſeparate from each other, like oil from water, according to their reſpective gravities. Thus if nearly equal parts of gold and ſilver are melted haſtily together, and granulated by pouring into cold water, although the particles of gold and ſilver cannot be diſtinguiſhed from each other by their external characters, yet they may be eaſily made to ſeparate by melting the maſs at a very gentle heat, keeping it in fuſion for a quarter of an hour more or leſs, and then allowing it to cool gradually; the crucible being now examined, will be found to contain the gold, alloyed with a ſmall variable proportion of ſilver in a lump at the bottom, and the reſt of the ſilver wholly free from gold, lying upon it.[c] It ſeems however by no means to be a neceſſary conſequence of this fact, that the maſs in queſtion was not a proper alloy: the ſtrong affinity of coheſion that ſubſiſts between the particles both of gold and ſilver, the great difference between their ſpecific gravities, and the temperature at which they become liquid: all theſe forces concurring together in the moſt favourable circumſtances, may well overcome a conſiderable degree of chemical affinity. Still leſs can it be hence inferred that no proportions of gold and ſilver can form a proper alloy.

Another objection to the method juſt mentioned of diſtinguiſhing alloys from mixtures, is, that it is applicable only to a very few caſes. When, for example, a mixture of copper and lead is to be ſubjected to this trial, as ſoon as the ſeparation begins to take place, part of the lead will occupy the bottom of the crucible, while the reſt ſtill mixed with the copper, will float above it: in proportion as the proceſs goes on, and the copper becomes purer, a greater heat will be required to keep it liquid; the lead will then begin to boil, and particles of this metal in vapour will be conſtantly thrown up into the copper, ſo as to prevent the compleat parting of the two, even ſuppoſing that no chemical affinity whatever ſubſiſted between them. With ſtill more force will this objection apply

[a] Eſſ. des Mines et des Metaux. p. 256. [b] Phil. Trans. for 1803. p. 119. [c] Lewis. Comm. Arts. p. 86.

to a mixture of iron with any other metal that is heavier and more fusible than itself.

The evidence of chemical affinity between metallic substances, is of the same kind as in other cases, consisting either of an entire change of properties, or in such modifications of them, as are obviously not intermediate between those of the constituent parts. These we shall proceed to mention, premising however that there are more doubts and difficulties on this subject, than in any other department of chemical science.

It is a striking proof of affinity between two metals, when one being applied in vapour to the surface of another, of much greater fixity, and at a high temperature, quits its gaseous form without any diminution of heat, and enters into intimate union with it. Thus if a small crucible containing gold, is inserted into a larger one, and some bismuth be scattered in the space between, and the apparatus be raised to a white heat in order to melt the gold, the bismuth at this high temperature will be for the most part reduced to vapour, yet upon examination, the gold will be found to have combined with part of it,[d] thus shewing that the affinity between these two metals is so great as to overcome the opposition presented by the difference in their specific gravities, and the elastic state of the bismuth.

The remarkable difference between the fusibility of some alloys and that of their constituent ingredients, may be considered as another sign of real affinity. As far as experiments have been instituted on this subject, it appears that the point of liquefaction in almost all alloys is lower than would have been inferred from the mean fusibility of their elements. Thus a mixture of gold and iron will melt at nearly the same temperature that is required for the fusion of gold alone. In some cases the fusibility of the alloy is even greater than that of its most fusible ingredients: thus an alloy of tin, lead, and bismuth, will become fluid in boiling water, a heat not sufficient for the melting even of bismuth, the most fusible of the three.

Some metals appear capable of uniting with each other in any proportions, as gold and copper, lead and tin, lead and silver, &c.: others are said to combine only to saturation, as silver and iron, lead and iron;[e] of this however there seems to be some doubt; while a few have been reckoned absolutely incapable of combination; thus quicksilver is supposed not to unite with either iron, cobalt, or nickel. Something however in these three instances is to be attributed to the hardness of the metals, and to their requiring for their fusion, or even softening, a heat much greater, that will entirely volatilize quicksilver, so that the circumstances most favourable to combination cannot in these cases be brought about. Thus much however is certain, that if iron be previously combined with tin or zinc, the mixture will dissolve in mercury without difficulty, forming in the first instance a magnetic, and in the latter an unmagnetic triple alloy.[f]

The durability of alloys is in most cases much less than might be supposed from that of their component parts; so generally indeed does this happen, that Macquer and Gellert are inclined to deny to those metallic mixtures that are ductile, the name of alloys. This however is clearly carrying the matter to an excess. Some very ductile metals are rendered perfectly brittle by the addition of a very minute proportion of even another ductile metal, as is strikingly the case with the alloy of lead and gold: half a grain of the former rendering an ounce of the latter extremely spungy and brittle.[g] In many of the brittle alloys however a variation in the proportion of the ingredients will so greatly modify this quality, without materially affecting the others, as to render it probable that brittleness is rather a proof of supersaturation than of chemical union. Iron when combined with about a fifth of tin, forms a white alloy, whose fusibility, specific gravity, &c. clearly demonstrate a chemical union, yet the compound is very soft and ductile: but when the proportion of tin is rendered equal with that of the iron, the mass is perfectly brittle. So in like manner copper, with $\frac{1}{15}$ of tin forms a malleable alloy, but if the tin is increased to $\frac{1}{3}$ of the whole, the alloy is brittle.[h] Even brass, which when made of eleven parts copper to one of zinc, is more malleable than copper itself, becomes brittle when the zinc forms $\frac{1}{3}$ of the mass.[i]

In determining the difference between metallic mixtures and alloys, great stress has been laid on the specific gravity, and wherever this has been found to differ from what by calculation ought to have been the result, the mixture has been considered as a proper alloy without any further enquiry. The ascertaining of specific gravity however, is in common cases attended with considerable difficulty, and when

[d] Hatchett, Phil. Trans. for 1803. [e] Guyton, An. de Ch. xliii. 47. [f] Own Exper. [g] Hatchett, Phil. Trans for 1803. p. 70. [h] Journ. de Phyf. xii 320. [i] Ibid. p. 318.

the ſpecific gravities of various metals and metallic mixtures are to be compared with each other, the ſources of error are ſo multiplied, as to render it difficult even for the moſt ſkilful to avoid falling into error. In the firſt place, care muſt be taken that the alloy and the ingredients of which it is compoſed, are under ſimilar circumſtances of compreſſion: copper and gold in the ſtate of wire, are ſpecifically heavier than the ſame metals that have ſimply been fuſed; if therefore we melt together equal weights of copper wire of the ſpecific gravity 8.87 and laminated gold, ſpecific gravity, 19.36 and find that the ſpecific gravity of the button of alloy inſtead of being equal to 14.11 is conſiderably leſs than the mean of its component parts, we ſhall yet by no means be juſtified in inferring from this fact that chemical union has taken place. The ſpecific gravity of copper ſlowly cooled, and not wire-drawn, is only 7.78 and that of gold in the ſame circumſtances, is 19.25, and this being alſo the ſtate of the alloy, its calculated ſpecific gravity, inſtead of being 14.11, ought to be eſtimated only at 13.51. Much alſo depends on the nature of the mould in which the alloy is caſt; the ſpecific gravity of the ſame individual maſs being always leſs when caſt in ſand, than in iron. Thus Mr. Hatchett[k] found the ſpecific gravity of gold, made ſtandard by Britiſh copper, and caſt in iron, to be 17.281, while the ſame, caſt in ſand, was only 16.994.

Another circumſtance as yet unattended to, and which influences the ſpecific gravity of metals, whether pure or mixed, has been aſcertained by the accurate chemiſt above mentioned.[l] It is this: if the mould is not placed horizontally, the lower part of the bar or ingot will have to ſuſtain not only the weight of the atmoſphere, but alſo that of the upper part of the bar: hence there will be a difference in gravity between the top and bottom of an ingot, which will vary according to its length, and the horizontal angle in which it was placed while caſting. Nor is this difference ſo trifling as might at firſt be ſuppoſed: a bar weighing twelve ounces of ſtandard gold, was caſt in a vertical poſition, and on an accurate examination, the ſpecific gravity of the top was 17.035, and that of the bottom was 17.364: nor was this in any degree owing to the unequal diſtribution of the copper, for the proportion of pure gold in both pieces was preciſely the ſame.

If however theſe cauſes of error are properly attended to and obviated, there ſeems no reaſon why a change of ſpecific gravity may not in theſe, as in other caſes, be looked upon as an evidence of chemical combination. The bulk of ſome metallic mixtures is greater, and of others leſs, than that of their component parts, but we are by no means in poſſeſſion of a ſufficient number of accurate experiments, to draw any general inferences from this variation.

In a few caſes the colour of an alloy may be conſidered as indicative of chemical union, being by no means intermediate between that of its elements: of this kind is the golden colour of the alloy of copper and zinc, and the ſilver hue of arſenicated copper; but the general ſimilarity of colour between the white metals and their alloys, confines the application of this external character to a very few inſtances.

The moſt important but the moſt difficult inveſtigation reſpecting the mutual action of metals on each other, is the elective affinity which has been obſcurely obſerved in a few caſes, and doubtleſs by proper attention may be traced in many more. In all inſtances where this takes place, there can be no queſtion whether the ſubſtance operated on is a proper alloy or a mere mixture, the diſcovery therefore of facts of this kind is of peculiar importance. An amalgam of biſmuth, is in part decompoſed by allowing a bar of lead to remain ſuſpended in it, a portion of the lead is diſſolved, and the remainder is ſtudded with cryſtals of biſmuth, gradually depoſited in the ſame manner as a piece of zinc decompoſes a ſolution of acetite of lead.[m]

The above are the principal general circumſtances that have been obſerved concerning the action of metals on each other, a ſubject that may demand the abilities and will recompenſe the attention of the greateſt and moſt accurate chemiſts, and which unfortunately has hitherto received leſs elucidation from the ſuperior knowledge and ſkill of modern philoſophers than any other branch of chemical ſcience.

ALUDEL. An article of chemical apparatus. (See the Appendix.)

ALUM. *Alaun*, Germ. *Alun*, Fr. Στυπτηρια Gr. *Alumen*. Lat.

This ſalt, improperly denominated Sulphat of Alumine, in the modern nomenclature, is by far the moſt important of all thoſe with earthy baſes: we ſhall therefore treat of it conſiderably at length.

Much uncertainty prevails reſpecting the knowledge which the ancients poſſeſſed of this ſubſtance. The στυπτηρια of Dioſcorides,[n] and

[k] Phil. Tranſ. for 1803. p. 118. [l] Ibid. p. 123. [m] Own Exper. [n] Dioſcor. V. ch. 123.

Alumen of Pliny,[b] appear to comprehend a variety of ſaline preparations, reſembling each other only in their ſtyptic taſte. We may however with tolerable certainty refer the σχιστὴ or *trichitis*, to the native alum of modern mineralogiſts, while the νιτρα or *liquidum*, appears to be ſimilar to the preſent manufactured Levant alum. This laſt is deſcribed by the authors above mentioned, as of an uniform texture, limpid, milk-white (probably on the outſide) and in great uſe for dying wool of bright colours: it is characterized by Pliny, as ſtriking a black colour with pomegranate juice, whence we may infer that it contained a ſmall proportion of ſulphat of iron, as the commoner kinds of alum do at preſent. Of the particular method of manufacturing it, we are almoſt wholly unacquainted; Pliny merely mentioning that it was made from water and mud, or in other words, by lixiviation. The beſt was obtained from Egypt, and the iſland Melos; it was alſo prepared in Cyprus, Sardinia, and the Lipari iſlands.

In the middle ages, alum-works were eſtabliſhed at Roccha in Syria, [c] (formerly called Edeſſa) whence the commercial name of Roch alum, at Foya Nova, near Smyrna, and in the vicinity of Conſtantinople. From theſe places the Genoeſe, and other commercial ſtates of Italy, procured the alum with which they ſupplied the Weſtern and Northern parts of Europe. About the middle of the fifteenth century this manufacture was introduced into Italy, and the eſtabliſhments of La Tolfa, Viterbo, and Volaterra, ſoon acquired an importance which induced Pope Pius II. to prohibit the uſe of Oriental alum. Early in the ſixteenth century the art of preparing this ſalt extended to Spain and Germany. The alum works of Whitby in England, were eſtabliſhed in the reign of Elizabeth, by Sir Thomas Chaloner: and in the ſeventeenth century the manufacture of alum began to be undertaken in Sweden.

Alum was well known by the older chemiſts to contain an earth in combination with ſulphuric acid: but from its being precipitable in a white pulpy maſs by a carbonated alkali, and being again ſoluble with efferveſcence in an acid, the common opinion for a long time was that this earth was the calcareous, and therefore that there was a conſiderable analogy between alum and ſelenite. Geoffroy, Baron, Hellot, and Pott, in their intereſting experiments on this ſalt, ſhewed that its earthy baſe was contained in clay; and Marggraf in his two memoirs on this ſubject,[d] made a ſtill nearer approach to the knowledge of its conſtituent parts. He ſhewed that the precipitated earth of alum, when well waſhed, is reſoluble in ſulphuric acid, even after it has been calcined, but that this ſolution yields on evaporation only a ſaline magma, inſtead of cryſtals of alum: the ſame effect takes place if a native clay is uſed, inſtead of the earth of alum. This able chemiſt alſo proved that the addition of a little potaſh to the ſulphat of alumine, communicated to it the property of depoſiting octahedral cryſtals of genuine alum: he ſeems however to have conſidered the alkali only to be of uſe in combining with and neutralizing a certain oily or greaſy matter, which by adhering to the cryſtalline plates of the magma, prevented them from coaleſcing into hard and perfect cryſtals. The eſſay of Bergman, [e] on the preparation of alum (publiſhed firſt in 1767) added conſiderably to our knowledge of the ingredients and chemical properties of this ſalt: it is here ſhewn that a ſmall exceſs of acid is neceſſary to the conſtitution of alum, ſince, when this is taken away, its taſte, ſolubility, and cryſtallizability are deſtroyed. The author alſo mentions in the ſame treatiſe, that thoſe lixivia, which on account of their great exceſs of acid cannot by mere evaporation be made to depoſit alum, may be brought to a cryſtallizable ſtate by the addition of potaſh or ammonia, but not by means of ſoda or lime. He further obſerves, that vitriolated potaſh and alum combine into a triple ſalt; yet is by no means of opinion that *all* alum neceſſarily contains either potaſh or ammonia; on the contrary he recommends the acid uncryſtallizable lixivia to be treated with clay, in order to neutralize their great exceſs of acid, and diſpoſe them to depoſit a larger quantity of cryſtals than could be procured from the addition of potaſh. This propoſed improvement of the manufacture was introduced without ſucceſs into ſome of the German eſtabliſhments, and many of the chemiſts of that nation began to conſider alum as a proper triple ſalt, in which the preſence of potaſh or ammonia was abſolutely neceſſary: Profeſſor Hildebrand, and Klaproth, in particular, were decidedly of this opinion. It is to the accurate and indefatigable Vauquelin, however, that chemiſtry is indebted for the lateſt and moſt ſatisfactory experiments on this ſubject, which have ſcarcely left any thing further to be known relative to the compoſition of this ſalt.

[b] Plinii, Hiſt. Nat. L. xxxv. § 52. [c] Bergman, Eſs. v. i. p. 338. [d] Mem. de l'Acad. de Berlin, 1754. p. 31. [e] Berg. Eſſ. v. i.

[f] He firſt diſſolved in pure ſulphuric acid ſome alumine equally pure, and then evaporated the ſolution repeatedly to dryneſs, in order to drive off the exceſs of acid: the dry pulverulent reſidue being then re-diſſolved in water, was brought by evaporation to various ſtates of ſpecific gravity, for the purpoſe of cryſtallization; but notwithſtanding every precaution, a flaky cryſtalline reſidue was all that could be procured. The ſolution which had thus conſtantly refuſed of itſelf to yield cryſtallized alum, began to depoſit ſome immediately on the addition of a few drops of carbonated potaſh, and by accurately proportioning the alkali, the whole of the liquor, to the very laſt drop, was made to furniſh by evaporation octahedral cryſtals of alum.

Another portion of the ſame pure aluminous ſulphat was mixed with the ſame quantity of carbonated ſoda as had been employed of potaſh in the preceding experiment, but no cryſtals were depoſited, even by evaporation. Nor were lime or barytes more efficacious. Hence it may be inferred that alum is by no means a pure ſulphat of alumine, and that the uſe of potaſh in promoting its cryſtallization is not to ſaturate a ſuppoſed exceſs of acid. This was further demonſtrated by ſubſtituting ſulphat of potaſh and ſulphat of ammonia for theſe alkalies in their pure or carbonated ſtates, in which caſe, being already ſaturated with ſulphuric acid, they could not poſſibly contribute to deprive the aluminous ſulphat of a ſuppoſed exceſs of the ſame acid; yet, in this caſe as in the former, the uncryſtallizable ſulphat of alumine was made to depoſit cryſtals of genuine alum. The ſame effect took place even when acidulous ſulphat of potaſh was ſubſtituted to common ſulphat of potaſh.

It had been obſerved by Bergman, and other chemiſts, that a ſolution of common alum, if boiled with clay or pure alumine, loſes by degrees its acid taſte, becomes ſuperſaturated with earth, and is no longer ſoluble in water: in this ſtate it was called alum ſaturated with its own earth. This fact alſo was examined into, and ſtill further elucidated, by M. Vauquelin. He found that a long continued boiling was neceſſary to produce this effect, and that the earthy alum thus formed, retained the potaſh, or ammonia, which it poſſeſſed in its ſoluble ſtate, ſince by diſſolving it in dilute ſulphuric acid, octahedral cryſtals of alum were depoſited. He further ſhewed that the preſence of potaſh or ammonia was abſolutely neceſſary to render the alum thus ſuperſaturated, inſoluble: for by boiling pure acid ſulphat of alumine with an additional portion of earth, the acid became completely ſaturated, but no precipitation enſued: having then added a few drops of ſulphated potaſh, a depoſition took place ſhortly after, poſſeſſing all the properties of the above-mentioned ſaturated alum. Another curious fact aſcertained on this occaſion was, that when alum contains a larger proportion of potaſh than uſual, the form of its cryſtals, inſtead of being octahedral, becomes cubical, without any other remarkable change of properties.

Hence it appears that there are ſeveral varieties of ſalts, compoſed wholly, or for the moſt part of ſulphuric acid and alumine, clearly diſtinguiſhable from each other, though generally confounded together under the common and vague name alum.

1. The firſt is ſulphat of alumine, being a ſaturated combination of alumine and ſulphuric acid.

2. The ſecond is acid ſulphat of alumine, and differs from the preceding only in containing an exceſs of acid.

3. The third is acid ſulphat of alumine with potaſh, cryſtallizing in octahedrons.

4. The fourth is acidulous ſulphat of alumine with potaſh, cryſtallizing in cubes.

5. The fifth is ſulphat of alumine with potaſh, or alum neutralized by its own earth, pulverulent, inſipid, inſoluble in water.

6. The ſixth is acid ſulphat of alumine with ammonia.

7. And the ſeventh is acid ſulphat of alumine with potaſh and ammonia, or the common alum of the ſhops.

The analyſis of alum, when it was ſuppoſed to conſiſt only of ſulphuric acid, alumine, and water of cryſtallization, was very ſimple. Bergman recommends to take a given weight of alum and calcine it in a full red heat, in order to drive off the water of cryſtallization, the amount of which is indicated by the loſs of weight in this proceſs. A freſh portion of ſalt is then to be diſſolved in water, and decompoſed by the addition of carbonated potaſh; the precipitate, when well waſhed and ignited, indicates the proportion of earth; and the quantity of ſulphuric acid is either eſtimated from the known weight of water and alumine obtained in the previous proceſſes, or may be calculated from the ſulphat of potaſh reſulting from the evaporation of the reſidual liquor, after the ſeparation of the alumine. The imperfections

[f] An. de Chim. v. xxii. p. 258.

however of this method are too obvious to need pointing out; we ſhall therefore proceed to notice the mode made uſe of by Vauquelin.

He firſt reduces a ſmall piece of alum to powder, and adds to it a ſolution of cauſtic potaſh, in ſufficient quantity to decompoſe it entirely; if then upon gently heating it gives out an ammoniacal odour, as is generally the caſe, this ſhows the preſence of ſulphated ammonia. Having obtained this indication, he diſſolves three hundred grains of the alum in diſtilled water, puts the liquor into a tubulated retort, and adds quick lime equal in weight to the ſalt: by making this mixture boil for about twenty minutes, the whole of the ammonia is expelled, and may be condenſed by cold water in the receiver, or in a Woulfe's apparatus: this ammoniacal liquor being then carefully ſaturated with ſulphuric acid, and cryſtallized, will ſhow the quantity of ſulphated ammonia. The reſidue in the retort being mixed with warm water, and filtered, a clear liquor is obtained, containing the ſulphat of potaſh, with ſome ſelenite, which laſt being got rid of by boiling and evaporation, the remaining fluid will then depoſit the ſulphat of potaſh in a cryſtalline form. When the previous aſſay does not indicate the preſence of ammonia, the alum is to be decompoſed by cauſtic ammonia, the precipitate is to be well waſhed, and the liquors, being added together, are to be gently evaporated to dryneſs: the ſalt thus obtained, is heated in a crucible, till it ceaſes to exhale white vapours of ammoniacal ſulphat, and the reſt is ſulphat of potaſh. The objections to which this proceſs is liable are, firſt, that the oxyd of iron is not at all noticed; ſecondly, that the lime will in part decompoſe the ſulphat of potaſh; and thirdly, that the alumine, when mixed with lime, cannot without a long proceſs be again ſeparated. The following is, perhaps, upon the whole, the moſt accurate way of analyſing the ſalt in queſtion.

1. Of 1200 grains of alum take 400, and make a ſaturated ſolution of it in diſtilled water; add to this, in a tubulated retort, 400 grains of quick lime; boil the mixture for a quarter of an hour or twenty minutes, and the water condenſed in the receiver will contain the whole of the ammonia. Saturate this accurately with ſulphuric acid, and evaporate the liquor to dryneſs, continuing the heat till nothing remains behind but perfectly dry ſulphat of ammonia.

2. Having thus aſcertained the ammoniacal ſalt, take another 400 grains of alum, and ignite it in an open crucible for a quarter of an hour; the loſs of weight which it thus undergoes indicates the quantity of water of cryſtallization and ſulphat of ammonia, the only volatile ingredients that it contains; but the amount of the latter of theſe having been determined in the firſt proceſs, that of the former is alſo found by ſimple ſubtraction.

3. Take, laſtly, the remaining 400 grains, and diſſolve them in water to ſaturation; to this add liquid ammonia, as long as it occaſions any precipitate; warm the mixture, and let it ſtand for ſome hours in a jar for the earth to ſubſide; decant off the ſupernatant fluid, and replace it by more ammonia; then transfer the whole into a flaſk, and heat it moderately; return it afterwards into the jar, and when it has ſtood ſome time, pour off the clear liquor; waſh the precipitate repeatedly with warm water, and transfer it to a filter to dry. The precipitate contains the alumine and oxyd of iron, all the other ingredients of the alum remaining in ſolution. When the precipitate is moderately dry, boil it in a flaſk with cauſtic potaſh; the earth will be diſſolved, and the oxyd of iron may be ſeparated by the filter, and requires afterwards to be waſhed and ignited; the alumine is then to be ſeparated from its diluted alkaline ſolution, by being boiled with muriat of ammonia, and when waſhed and ignited, remains pure. We now return to the ammoniacal ſolution, into which, when previouſly neutralized by nitric acid, nitrat of barytes is to be dropped as long as any precipitate takes place: the ſulphat of barytes thus procured denotes the quantity of ſulphuric acid in the alum. The reſidual liquor now holding the nitrats of potaſh and ammonia, is to be evaporated nearly to dryneſs, at which period, a ſufficient quantity of ſulphuric acid being added, a further application of heat will drive off the nitric acid and ſulphat of ammonia, leaving behind the ſulphat of potaſh. Thus we obtain the quantity of ſulphat of potaſh; that of the ſulphat of ammonia being known by the firſt proceſs, and that of the whole ſalt being indicated by the ſulphat of barytes.

We ſhall now proceed to notice the manufacture of this ſalt. The earlieſt author who treats on this ſubject is Agricola,[s] and he gives us a ſingularly perſpicuous and ſatisfactory account of the methods purſued in his time, (about 1530,) for extracting alum from its earthy, ſtony and pyritous ores. He remarks that the lixivium, beſides alum, contains ſulphat of iron, which may either be cryſtallized with

[s] De re Metallica, p. 456.

the alum, and ſeparated afterwards by hand, or the ſulphat of iron may be deſtroyed by the addition of a proper quantity of urine. He alſo mentions that the earthy ſediments in the various proceſſes are not thrown away, but expoſed for a time to the air, and then boiled with water and urine, by which management the ore may be made repeatedly to yield as much alum as it did at firſt. It is remarkable that he does not mention a word of the uſe of potaſh, nor is it very clear by whom, or at what period, the uſe of this alkali was introduced into the manufacture.

The ſimpleſt proceſs by which alum is prepared is that in uſe at the Solfatara, near Naples. It has been deſcribed by the Abbé Mazeas,[h] and Fougeroux de Bondaroy.[i]

The Solfatara, called by the ancients Forum Vulcani, Campi leucogei, is a ſmall plain on the top of a hill, covered with a white ſoil, in which are perceived numerous round holes or craters, from which ſulphureous vapours are conſtantly aſcending. The ground, even at the ſurface, is conſiderably warm, and at the depth of a very few inches is ſo hot as to be intolerable to the hand. It is celebrated by Pliny (Nat. Hiſt. lib. xxx. ch. 50.) for its ſulphur, but the alum eſtabliſhment is of a much later origin. The white clayey ſoil of this plain, being penetrated and entirely impregnated by ſulphureous vapours, forms a rich ore of alum, as may be aſcertained by its ſtrong ſtyptic taſte when applied to the tongue. In order to extract the ſalt, a ſhed is erected, in the middle of which is placed a large oblong leaden ciſtern, let into the ground almoſt up to the brim, in order to receive a proper quantity of the ſubterranean heat: this ciſtern is ſurrounded by ſmaller cauldrons, let into the ground in the ſame manner. When all is prepared, the extraction of the alum begins by putting ſome of the aluminous earth into the ciſtern, and pouring water upon it; this mixture is carefully ſtirred, till the whole of the ſalt is diſſolved; after which, the earth being removed, a freſh portion is put in, ſo as to bring the water almoſt to a ſtate of ſaturation. The liquor is now removed into the ſmaller cauldrons, and the loſs by evaporation is ſupplied by freſh liquor, till a pellicle begins to appear on the ſurface. It is then removed into tubs, where, as it cools, it depoſits a large quantity of cryſtals of alum. The mother liquor is returned to the ciſtern, where it is mixed with earth as before. The cryſtals of alum are purified by a ſecond ſolution and cryſtallization, after which they are fit for the market. Hence it appears that the alum exiſts ready formed in the earth of the Solfatara, and that the whole of the manufacturing part is reduced merely to lixiviation and purification. This alum, from the careleſs method of preparing it, is conſiderably fouled by ſulphat of iron, and is in conſequence little known beyond the Neapolitan territories. The proportion of alum contained in the ore muſt of neceſſity be very various; a ſpecimen, analyſed by Bergman, yielded only eight per cent. whereas the Abbé Mazeas procured, by ſimple lixiviation, two pounds and a half of cryſtals from ſix pounds of the earth, or about forty-one per cent. It is obſervable that no addition of potaſh or ammonia is made in this manufacture, the alkali muſt therefore exiſt in the ore. As no analyſis has been made of this alum, it is impoſſible to tell which alkali it contains.

The alum works of La Tolfa, near Civita Vecchia, in the Roman ſtate, are among the oldeſt in Europe, and as the alum manufactured here is reckoned the pureſt of any, we ſhall give a detailed account of the proceſs, as reported by the Abbé Mazeas and Fougeroux de Bondaroy,[k] to whom we have already been indebted for the preceding particulars.

The ore made uſe of at La Tolfa, is the ALAUNSTEIN of the Germans, which is procured about a mile off the place where it is manufactured. It is found in irregular ſtrata, and deep, almoſt perpendicular, veins in the ſide of a hill; and when unmixed with other ſubſtances, is of a yellowiſh white colour, and ſo hard as to require blaſting by gunpowder. Being broken into pieces of a moderate ſize, it is firſt of all roaſted. The furnace made uſe of for this purpoſe is a cylindrical cavity in a maſs of maſonry, the greater part of which is occupied by a hemiſpherical dome, with a large round aperture in its top. The fuel, which is wood, is conveyed by a ſide door into the dome, and the alum ore is piled ſkilfully over the aperture, ſo as to form a ſmaller dome, whoſe diameter is equal to that of the aperture in the lower one. As ſoon as the fire is kindled, the ſmoak and flame penetrate through the interſtices of the pieces of ore, and quickly heat the whole maſs. For the firſt three or four hours, the ſmoak eſcapes in denſe black volumes, but by degrees it acquires a whiter colour, the pieces of ore become of a light red or roſe colour, and a faint ſmell of liver of ſulphur becomes manifeſt. At the end of twelve or fourteen hours

[h] Mem. de l'Acad. des Sciences, vol. v. p. 389. [i] Ditto for 1765, p. 275. [k] Ditto for 1766, p. 1.

the fire is extinguiſhed, and when the alum ſtones are grown cool, they are taken down, and again arranged in the ſame manner as before, only obſerving to place thoſe pieces near the centre of the fire which were before at the ſides, that the whole may be equally calcined. The ſecond roaſting continues nearly as long as the firſt, and the ſtones are conſidered to have been properly managed if they are of an uniform white colour, and conſiderably ſtyptic when applied to the tongue.

The ſecond proceſs commences by piling the ſtones upon a ſmooth ſloping floor, in long parallel ridges, between each of which is a trench filled with water; from this trench the beds are frequently ſprinkled, in proportion as they become dry by the action of the ſun and wind. After a few days the pieces of roaſted ore begin to ſwell and crack, and fall to powder like quick lime when it is ſlacked, acquiring at the ſame time a light reddiſh colour; and at the end of forty days, more or leſs, this operation is compleated. Its ſucceſs is materially influenced by ſunſhiny weather, the hotteſt periods of the year producing the beſt alum, and in the largeſt proportions, while long-continued rains entirely exhauſt and ſpoil the ore.

The next ſtage of the manufacture conſiſts in diſſolving the alum out of the ore, and diſpoſing it to cryſtallize. For this purpoſe a leaden boiler is filled two-thirds with water, and portions of the decompoſed ore are ſucceſſively ſtirred in, till the veſſel is nearly full: when the liquor begins to boil it is diligently ſtirred up from the bottom, that the whole of the alum may be diſſolved, and the waſte by evaporation, is ſupplied from time to time by the mother water of a preceding cryſtallization. At the end of about twenty-four hours the fire is extinguiſhed, and the liquor is left at reſt for the particles of earth to ſubſide; as ſoon as this has taken place, a ſtop-cock, fixed in the ſide of the boiler, about one-third of its heighth from the bottom, is opened, and the clear ſolution is transferred along a wooden ſpout, into ſquare wooden reſervoirs, ſeven feet high by five wide, ſo conſtructed as to be readily taken to pieces; in theſe it remains about a fortnight, during which time the alum cryſtallizes in irregular maſſes upon the ſides and bottom. The mother liquor is of a fleſh colour and unctuous appearance, and ſtill rich in alum, it is therefore tranſferred into ſhallow receptacles, where it depoſits, after a time, both earth and cryſtals; theſe latter are taken out and ſeparated from the impurities by waſhing in the reſidual fluid. Finally, this fluid itſelf is let out into a deep reſervoir, whence it is pumped, to be mixed with freſh water and earth in the leaden boiler, as already mentioned. The earth, after having been once lixiviated, is thrown away, although by ſimple boiling with ſulphuric acid, it may be made to yield a conſiderable quantity of pure alum.

From the analyſis which has been already given of the ore of La Tolfa, under the article Alaunſtein, it appears to contain all the component parts of alum, but over-loaded with earth and intimately mixed with ſilex: the chief advantage in the proceſs of roaſting, to which it is ſubjected previous to lixiviation, is probably the cracking of the ſtony maſſes in all directions, ſo as to render them eaſily diſintegrable by the action of water. No alkali is added in the manufacture; the whole therefore of that contained in the alum, muſt have preexiſted in the ore. By the analyſis of Vauquelin,[l] the alum of La Tolfa contains

49. ſulphat of alumine,
7. ſulphat of potaſh,
44. water.

100.

Hitherto we have noticed only thoſe ores which afford alum without the addition of potaſh or ammonia: by far the greater part however of the European alum is prepared from the aluminous ſlate (Alaunschiefer), or the aluminous earth (Alaunerde), and as theſe minerals contain only the remote principles of this ſalt, a much more complicated proceſs is required than where the alum exiſts ready formed in the ore.[m] The only neceſſary ingredients in the pyrito-aluminous ores are clay and pyrites, or ſulphuret of iron; in addition however to theſe, there is always a variable proportion of bitumen, lime, and magneſia.

It is well known that iron pyrites, by the combined action of air and moiſture, is converted into ſulphat of iron, in conſequence of the oxydation of the metal and the acidification of the ſulphur: we know alſo that this ſalt, by further expoſure to the air, undergoes a partial decompoſition; the iron becoming highly oxydated, is incapable of combining with ſo large a proportion of ſulphuric acid as it was united with before, in conſequence of which a portion

[l] An de Chim. vol. xxii. [m] Jars Voyages Metallurg. v. iii. p. 287. Bergman Eſſ. v. i. Journ. des Mines, No. 46. An. de Chim. vol. xxix. p. 247.

of ſulphuric acid is ſet at liberty, to combine with that ſubſtance in the ore with which it has the greateſt affinity. This ſubſtance is the lime, ſulphat of lime will therefore be produced; and when the whole of this earth is ſaturated, the magneſia will begin to combine with the acid: the only two remaining ſubſtances in the ore are alumine and ſilex, the latter of which being inſoluble in ſulphuric acid, the whole of what remains, after ſaturating the lime and magneſia, muſt combine with the alumine. The lime and magneſia are doubly hurtful, as they not only abſorb the acid in preference to the alumine, but their ſulphats remain in the mother liquor, and prevent the cryſtallization of a part of the alum. Hence it appears that if theſe alkaline earths exiſt in the ore in ſo great a proportion as to unite with the whole of the acid, no alum can be produced, and that the richeſt alum ore, *ceteris paribus*, is that which contains the leaſt of them.

The firſt proceſs in the manufacture of alum from the pyritous ores, is the acidification of the ſulphur, and the formation of ſulphat of alumine: to effect which the common practice is to roaſt the ore as ſoon as it is procured from the mine. Upon a hard floor of rock, or well rammed clay, is laid a bed of faggots and coal, which is covered all over to the thickneſs of two or three feet with pieces of ore: fire is now applied, and as the heat penetrates through the maſs, freſh quantities of ore are added, till the pile attains the heighth of thirty or forty feet. In Sweden, where they lixiviate the ſame parcel of ore repeatedly, the pile is built up with alternate ſtrata of freſh ore, and that which has already been uſed one, two, or three times. In two or three months the fire goes out of itſelf, and the ore, if properly roaſted, will be of a brown colour, and aſtringent to the taſte: a red colour indicates that the heat has been too great, and the produce of alum is conſiderably diminiſhed. The moſt judicious method, however, of preparing the ore for lixiviation, is that practiſed at Flone, in the department of l'Ourte, in France. When procured from the mine, it is ſorted, according to its degree of hardneſs, and laid lightly in heaps ten or twelve feet high, which are ſedulouſly watered during dry weather, as a certain degree of moiſture greatly haſtens this part of the proceſs. The ſpontaneous decompoſition of the pyrites, which is thus brought about, is very ſlow, the hardeſt kinds of ore requiring from three to four years. When upon examination the maſs appears ſufficiently impregnated with ſalt, the contents are made into a pile, with alternate ſtrata of faggots, and by a very judicious and gentle roaſting, the ſulphat of iron is for the moſt part decompoſed, and its acid, uniting with the alumine and the potaſh produced by the combuſtion of the wood, forms alum. After the ore has been prepared by one of the methods above mentioned, it is lixiviated. For this purpoſe large receptacles of wood, or maſonry, furniſhed with a double bottom and ſtop-cock, are nearly filled with the ore; upon which water is poured in various proportions, according to the cuſtom of the manufactory or the ſuppoſed richneſs of the materials. The moſt economical method is to let the water remain for twelve hours in the firſt reſervoir, containing ore that has been already twice lixiviated; then to tranſfer it for an equal time to that which has been once lixiviated; and laſt of all to mix it for the ſame number of hours with freſh roaſted ore; after which it is turned into a large vat, where the earthy ſediment is for the moſt part depoſited. The liquor is judged to be ſufficiently ſtrong if its ſpecific gravity is one-eighth greater than that of pure water, or 1.25.

The boiling down ſucceeds to the lixiviation, and is always performed in leaden veſſels, copper being for the moſt part too dear a material, and iron being attended with the inconvenience of decompoſing the alum in a conſiderable degree. The object in boiling is two-fold, firſt to evaporate a part of the water, and thus induce the ſalt to cryſtallize, and ſecondly to decompoſe the ſulphat of iron. The lixivium being mixed with the mother water of a former cryſtallization, is boiled for twenty-four or forty-eight hours, according to the concentration of the liquor; during which much ſelenite and oxyd of iron is depoſited, forming a cruſt at the bottom of the pan, that requires to be removed from time to time.

In Saxony, where the proportion of mother water is large, and the lixivium is brought to a high degree of concentration, the boiling continues without interruption for a week. At the end of theſe reſpective periods, the ſpecific gravity of the liquor is aſſayed by a leaden hydrometer, or by filling a bottle of known ſize with the liquor, and then aſcertaining by the balance the comparative weight between it and water. This being done, an alkaline ſolution is added, and the firſt cryſtallization is brought about. In the Saxon manufactories, where the liquor is uncommonly concentrated, as ſoon as the evaporation is finiſhed, the contents of the boiler are let out into a reſervoir, where they

are ſtrongly agitated for half an hour, during which time a certain proportion of ſoap-makers lees and putrified urine is added. At Saarbruck, the potaſh is added twelve hours before the boiling is finiſhed. In the Engliſh works, when the liquor appears by the hydrometer to be ſufficiently evaporated, the fire is withdrawn from the boiler, and a ſtream of impure alkaline lixivium, from kelp and ſoap-makers aſhes, is let into the liquor already in the boiler; at the ſame time the cock of the boiler is turned, ſo as to allow the contents of it to flow into a reſervoir, by which management the two liquors are ſpeedily and effectually mixed. It remains in this reſervoir for three hours, during which it depoſits an earthy and ferruginous ſediment, and becomes of a clearer colour; it is now transferred to another large vat, and has its ſpecific gravity again taken, according to which a greater or leſs quantity of putrid urine is added, to lower it to the required ſtandard; being then agitated briſkly for a quarter of an hour it is left at reſt, and in the courſe of five days the cryſtals are depoſited on the ſides of the veſſel. In ſome French and Swediſh manufactories, the liquor, after being boiled down, is merely agitated for ſome time, without adding any alkali, and then paſſed into the cryſtallizing tub. The rough alum, or of the firſt cryſtallization, is always contaminated by a ſmall quantity of ſulphat of iron, from which it is moſtly freed by waſhing in cold water, the latter ſalt being far more ſoluble in this fluid than the former. When waſhed it is ready to be refined; for this purpoſe a few hundred weights of alum are put into a pan, with as much ſoft water as is juſt ſufficient for its ſolution when boiling hot; after the ſolution is effected, ſome bullock's blood is added, for the purpoſe of clarification; and at the end of about ſix or eight hours, when the alum is held in ſolution by only a little more fluid than its own water of cryſtallization, the liquor is run into caſks, where it concretes almoſt entirely in a ſingle maſs. After ten or twelve days, the reſidual liquor is poured out, and the ſalt being broken into pieces of about a hundred weight, is ready for ſale.

It may appear remarkable, and contradictory to the experiments of Vauquelin, mentioned in the former part of this article, that in ſome of the alum works there ſhould be no addition, either of potaſh or ammonia, to the lixivium obtained from the pyritical ores, and yet that the produce of alum ſhould be ſuch as to render the manufacture a profitable concern. The proportion of alkali required however being no more than three or four per cent. ſo minute a quantity may well exiſt in the ore, without being detected by chemical analyſis, not to mention that part of it would undoubtedly be furniſhed by the wood with which the ore is roaſted, and that ammonia would be formed by the combuſtion both of the bitumen contained in the ore and of the coals with which in England at leaſt the wood is mixed.

The only manufacture of alum which has been conducted throughout on ſtrict chemical principles, is that eſtabliſhed ſome years ago by Chaptal, at Javelle, near Paris, with which we ſhall terminate our account of the modes of preparing this important ſalt.

According to the modern way of preparing Sulphuric Acid, the requiſite proportions of ſulphur and nitre being mixed together, are brought to combuſtion in a cloſe chamber lined with lead: the ſulphur is thus acidified and converted to vapour, which, by degrees, unites with the water with which the floor of the chamber is overſpread, and forms a diluted ſulphuric acid. A ſimilar proceſs was eſtabliſhed by Chaptal,[a] only ſubſtituting dried clay for the water, the reſult of which was ſo favourable, that a large manufactory on the ſame plan was ſet on foot, which has continued in full activity for ſeveral years, producing alum only inferior to that of La Tolfa.

The chamber in which the combuſtion is carried on is 91 feet long, 48 feet wide, and 31 feet in heighth, to the pitch of the roof. The walls are of common maſonry, lined with a moderately thick coating of white plaſter: the floor is a pavement of bricks, ſet in a mortar compoſed of equal parts of baked and unbaked clay; and this firſt pavement is covered by a ſecond, the bricks of which are placed ſo as to lie over the joints of the lower one, and are themſelves firmly connected to each other by a cement, compoſed of equal parts of pitch, turpentine and wax, made boiling hot, and poured between the joints inſtead of mortar. The roof is of wood, and the beams are ſet at much leſs diſtances than common; they are alſo chanelled with deep longitudinal grooves, for the purpoſe of receiving the planks that fill up the ſpace between the beams, ſo that the whole of this great area of carpentry does not preſent a ſingle nail. The chamber thus conſtructed, was covered on the ſides and top with a layer of the cement juſt mentioned, applied as hot as poſſible,

[a] An. de Chim. vol. iii. p. 46.

ſo as to penetrate into all the pores of the wood and plaſter; three more ſucceſſive layers were then laid on, and the laſt was poliſhed, ſo as to preſent an uniform even face. In order to prevent the wood-work of the cieling from warping, it was covered on the outſide with a thick coating of cement, and a light roof of tiles was laid over the whole. By ſubſtituting this cement for a lining of lead, a vaſt ſaving was effected in the firſt expence; and it has been found by long experience to require fewer repairs than even lead itſelf.

The clay made uſe of is of the pureſt kind, ſuch as pipe-clay, that it may contain neither lime nor magneſia, and as little as poſſible of iron. It is to be tempered with water, and made into balls, five or ſix inches in diameter: theſe being dried in the ſun are afterwards calcined in a furnace: the firſt effect of the heat is to blacken them; but ſoon after they become red hot, the carbonaceous matter which cauſes the blackneſs is burnt out. Being withdrawn from the fire and cooled, they are broken down into ſmall fragments, and ſpread over the floor of the chamber. In this ſtate they are expoſed to the vapour of ſulphuric acid, from the combuſtion of ſulphur and nitre, and in a few days the pieces are obſerved to crack and open, and to be penetrated with ſlender ſaline cryſtals. The earth being at length covered with efflorescences, it is removed from the chamber and expoſed to the air, under ſhelter of a ſhed, that the acid may be compleatly oxygenated and become thoroughly united with the earth. It is now lixiviated, and the liquor contains in ſolution little elſe than acidulous ſulphat of alumine: this being boiled down to the proper conſiſtence, a ſolution of acid ſulphat of potaſh (being the reſidue in the pots of combuſtion, from which the ſulphuric acid was produced in the chamber, and conſiſting of the alkaline baſe of the nitre, combined with ſome of the ſulphuric acid) is poured in: and the liquor being then transferred into a large vat, perfect cryſtals of alum are depoſited, which are afterwards refined in the uſual manner.

The advantages of this proceſs are numerous. It may be carried on wherever a proper ſupply of clay can be had. The ſpace taken up by the works is much leſs extenſive than what is required according to the common methods. The whole manufacture is performed in at moſt one third of the time uſually neceſſary. A large quantity of fuel is ſaved; the extraneous ſalts in the mother water are fewer; an important uſe is made of the reſidual ſulphat of potaſh; and laſtly, the alum itſelf is much purer than uſual, and almoſt equally well adapted to fix the delicate dyes as that of La Tolfa, the commercial price of which is generally about double that of the Engliſh alum.

Common alum, in whatever way it is prepared, is a ſalt of a ſweetiſh acidulous taſte, and extremely aſtringent. Its perfect cryſtalline form is that of a regular octahedron, compoſed of two fourſided pyramids, joined baſe to baſe: when cryſtallized on a flat ſurface, however, it more uſually exhibits only fourſided pyramids. It is not very ſoluble in cold water, but readily ſo in hot. At 144° Fah. Roman alum requires fourteen times its weight of water for ſolution; freſh cryſtallized alum, holding as much water of cryſtallization as poſſible, requires thirteen parts; and Engliſh alum requires fifteen parts;* but, at a boiling temperature, alum will diſſolve in leſs than its own weight of water. In a dry atmoſphere, this ſalt becomes ſlightly efflorescent; when expoſed to a moderate heat it melts, foams, and, as the water of cryſtallization evaporates, becomes of an opaque white, forming a ſpungy maſs called *burnt alum*. In this ſtate it is ſtill ſoluble in water, with the exception of a ſmall earthy reſidue. By expoſure to a full red heat, a ſmall proportion of ſulphuric acid is driven off, and the remainder is inſoluble in water.

Alum is decompoſable by being heated with carbonaceous matter, the reſult being ſulphuret of potaſh with alumine, which poſſeſſes the property of ſpontaneouſly igniting when expoſed to a moiſt air, (ſee PYROPHORUS.)

Alum is alſo in part decompoſable by the alkalies and alkaline earths, which abſtract a portion of its acid, and occaſion a precipitate of alumine, combined with potaſh and a little ſulphuric acid. A ſimilar effect is produced by iron, zinc, copper, and a few other metals.

Alum is alſo decompoſable by vegetable fibre, and both vegetable and animal colouring matter, which it will precipitate from their ſolutions in water, leaving this fluid wholly colourleſs.

The uſes of alum are various and important. It is an article of the Materia Medica; it is a neceſſary ingredient in moſt kinds of pigments and lake-colours, and in the various proceſſes of dying. All leather that is not tanned or dreſſed with oil is prepared for uſe by means of alum. It is uſed by candle-makers to harden their tallow and render it white; and an unauthorized

* An. de Chim. vol. xxii. p. 280.

uſe is occaſionally made of it by bakers in the preparation of the fineſt white bread.

ALUM, *Native*. Of this mineral there are two varieties.

Var. 1. Plume Alum, *Alumen Plumoſum*, Werner. *Feder Alaun*, Germ. *Alun de Plume*, Fr.

The colour of this ſubſtance is yellowiſh or greyiſh white; it conſiſts of ſlender irregular hair-ſhaped fibres, either ſingle or accumulated, and ſlightly adherent to each other. It is uſually opaque, but ſometimes tranſparent, and then poſſeſſes a ſmall degree of luſtre. It excites on the tongue a ſweetiſh acerb taſte, like common alum.

It is found effloreſcing on bituminous ſchiſtus at Göttwig, in Auſtria; on grey argillite in Carinthia; in clefts and caverns on Stromboli, the Solfatara, the grotto of San Germano, Miſeno, and other places in Italy.

The native alum of Miſeno has been analyſed by Klaproth,[a] who found that one hundred parts yielded, by ſimple ſolution and cryſtallization, forty-ſeven of perfect alum, and twenty-nine more by the addition of a little potaſh, the remainder being ſand, with a ſmall quantity of ſelenite and a ſlight trace of oxyd of iron.

Var. 2. Mountain Butter. *Alumen Butyraceum*, Werner. *Bergbutter*, Germ.

This differs from the preceding variety in being of a darker colour, and forming clots or lumps on the ſurface of aluminous ſchiſtus. At firſt it is very ſoft, with a waxy luſtre and unctuous feel, but by expoſure to the air it becomes harder and ſomewhat crumbly. Its taſte reſembles that of var. 1.

It occurs in many places where aluminous ſchiſtus is plentiful, and in a ſtate of decompoſition, as at Muſkaw, in Upper Luſatia. It has not yet been analyſed, but probably differs from the preceding in containing a larger proportion of alumine and iron.

ALUM SLATE, ſee ALAUNSCHIEFER.

ALUMINE. *Alaunerde; Reine Thonerde*. G. This term has been adopted in modern nomenclature, to ſignify the earthy baſis of alum, or pure clay. This earth is one of the moſt extenſively diffuſed in nature, its properties (at leaſt the moſt important of them) have been familiar to mankind from the earlieſt antiquity, and on every account it requires particular attention.

Alumine is no where found native in a ſtate of purity, and it is a little remarkable that in all the natural clays, in which ſome of its characteriſtic properties are the moſt conſpicuous, it never forms even half the compoſition, and generally no more than a third or a fourth; and on the other hand, it is found nearly uncombined in the hardeſt gems, and the corundum; minerals in which its exiſtence was for ages unſuſpected, till the experiments of the illuſtrious Bergman, and where it exhibits properties widely different from thoſe of clay. The term Alumine therefore is well choſen, both as it ſuggeſts the moſt important ſaline combination of this earth, and as it prevents thoſe erroneous ideas of its properties which might attach to the antient term clay.

We ſhall refer to the article CLAY (meaning by this appellation the natural earthy compounds poſſeſſed of plaſticity, and employed in the ſeveral manufactories of pottery, porcelain, bricks, &c.) the leading mineralogical and technical deſcriptions relating to this earth, and ſhall here only deſcribe the chemical properties of pure alumine.

Alumine when pure, is white, and without taſte or ſmell. The natural clays indeed, and the other earths that contain much alumine, have a peculiar earthy ſmell when breathed upon, which is a teſt of ſome uſe in mineralogy, but this appears to be owing to the combination of clay with the oxyd of iron, and certainly does not belong to pure alumine. This earth is incapable of artificial cryſtallization, nor is it like ſilex, found native in a ſtate of abſolute purity and cryſtallized. However, in one or two varieties of the corundum gems, alumine forms by far the greater part of their compoſition, and thus circumſtanced, this earth is regularly cryſtallized and intenſely hard. A peculiar difficulty lies in the way of aſcertaining the true ſpecific gravity of this earth, which we ſhall notice when we have mentioned the effect of heat and water: in the gems it is conſiderable, being from about 3.99 to 4.28.

Alumine, either as it exiſts in the natural clays or when prepared pure by art, till it has been expoſed to a red heat, unites readily with water into a very tenacious unctuous-feeling maſs, which differs from all other wetted earths in being ſo plaſtic that it may be turned on a wheel, or moulded into any form. On adding more water it becomes gradually and equally diffuſed, making the liquor uniformly milky, and remaining very long ſuſpended before it ſubſides. It is not however in any degree ſoluble in this fluid. Plaſtic clay retains water in greater quantity, and for a longer time than any other earth; on drying, if heated very gradually, it

[a] Analyt. Eſs. p. 266.

ſhrinks in every direction, and at laſt cracks into a number of pieces, and returns to its original ſtate. When thus dried at a moderate heat, it is ſoft, greaſy, brittle, and crumbly; when rubbed, it takes a good poliſh, and remains equally plaſtic as before, on the addition of freſh water. But if it is dried at a full red heat, it becomes extremely hard, ſo as to ſtrike fire with ſteel, is harſh to the touch, and now no longer miſcible with water into a plaſtic maſs, nor does it abſorb any ſenſible quantity of this fluid. Its original properties however are regained on ſolution in an acid, and precipitation by an alkali, or vice verſa.

Alumine in many inſtances gives its characteriſtic properties with reſpect to union with water, to a very large proportion of any other earth with which it is mixed. In the natural clays as we have mentioned, it never forms quite half the mixture. The very pure aluminous earth of Schemnitz, according to Klaproth,[a] contains only 45 per cent. of alumine, and in the beſt porcelain clays the alumine is ſeldom more than from 25 to 30.

The action of heat on moiſtened alumine is very ſtriking. The firſt effect is to expel moſt of the large quantity of water which it has abſorbed in becoming plaſtic. The greater portion of this fluid is expelled at a very low red heat, or at the point at which the earth aſſumes that entire alteration in its texture as to loſe the power of again uniting with the water which it has loſt. In conſequence of this it ſhrinks in every dimenſion. But the loſs of weight and diminution of bulk do not ſtop here, for they both continue (the former in a diminiſhing ratio, the latter tolerably uniformly) up to as intenſe a heat as has ever been produced in furnaces. Hence it is that clay by its *contraction* affords as certain an indication of increaſe of heat as all other bodies do by their *expanſion*: not that this earth however, is incapable of expanſion by heat; for, like every other ſubſtance in nature, alumine does indeed dilate when heated, and contract when cooled; but this is only obſerveable when the heat applied is not more than the higheſt to which it has been expoſed ſince its plaſtic ſtate: above this point the contraction peculiar to this earth (produced either by an actual loſs of water or a different arrangement of its component particles) begins again to operate, and the extreme limit of its ſhrinking has never yet been preciſely determined. A late eminent ſcientific manufacturer, Mr. Wedgewood, very ingeniouſly applied this property of clay to the conſtruction of a thermometer for meaſuring the more intenſe degrees of heat, where the common inſtruments were inapplicable; but ſeveral circumſtances appear to ſhew that, though a valuable inſtrument, it is not ſuſceptible of that degree of accuracy, which has been often attributed to it. (See PYROMETER).

Several experiments on the contraction of pure alumine by heat are related by M. Theodore de Sauſſure,[b] (the ſon of a moſt illuſtrious father) which bear ſuch internal marks of accuracy as at leaſt to require attention, if not to enſure conviction.

M. Sauſſure obſerves, that when alumine is precipitated from alum by ammonia or by carbonated ammonia, it is capable of exiſting in two forms, according to the manner in which the ſolution of alum was made; if no more water was uſed than neceſſary to diſſolve this ſalt, the precipitated earth when dried at about 80° is a white, friable, light, very ſpongy earth, ſticking to the tongue, which the author calls *ſpongy* alumine. But on the other hand, if the alum is diſſolved in a very large quantity of water, the precipitate dried at the ſame moderate warmth, will be tranſparent, yellow, brittle, cracking in the heat of the hand, like rolls of ſulphur, with a ſmooth conchoidal fracture, not appearing like an earth, not adhering to the tongue, and *not again miſcible* with water. This the author terms *gelatinous* alumine. At the above temperature of about 80° both ſpecies contain an equal quantity of water, though the ſpongy occupies ten or twelve times the bulk of the gelatinous. But at a higher heat they differ much in the power of retaining water. The ſpongy alumine loſes at a full red heat, rather leſs than is ſufficient to melt ſilver, all the water which it had abſorbed, amounting to 58 per cent; ſo that 100 parts dried at 80° are hereby reduced to 42, and loſe no further weight by the higheſt intenſity of heat that can be given. But the gelatinous alumine dried at 80° is ſaid by M. Sauſſure to loſe only 43 per cent. of its weight at a ſilver-melting heat, 48¾ at a heat of 130 of Wedgewood (or ſufficient to melt caſt-iron) and appears never at any higher heat to alter further in its weight.

The author gives in the following table the progreſs of the loſs of weight (which it muſt be obſerved he only attributes to the volatilization of water) experienced by 100 parts of gelatinous alumine in powder, firſt dried at about 80° Fahr. and afterwards expoſed to different tem-

[a] Analyt. Eſſays.

[b] Journ. de Phy. Tom. 52.

peratures, and accurately weighed after each experiment.

One hundred parts of the above alumine,

Fahr.		*Water.*
at 144	loſe	12.2
257	——	19.
369	——	23.7
482	——	27.2
Wedgewood.		
13	——	42.3
29	——	45
85	——	46
106	——	47.5
133	——	48.25
170	——	48.25

On this table the author makes the very ſenſible remark that the contraction of clay (in the higher heats at leaſt) cannot be excluſively owing to the loſs of water, or to any loſs ſenſible to the balance, ſince the diminution in weight from the thirteenth degree of Wedgewood to the higheſt intenſity of heat is very trifling, whereas the contraction in the bulk of the clay, within theſe terms, is more than a fourth of its bulk.

Pure alumine is infuſible in any heat that furnaces can procure, if not in contact with an alkali, or with any other earth which may operate as a flux. However, when expoſed to oxygen gas from the blow-pipe, ſupported on a piece of charcoal, both Ehrman and Lavoiſier found it converted into a milk white globule, imperfectly fuſed, and intenſely hard, ſo as to ſcratch glaſs nearly as the diamond. Some doubt however ariſes, whether the alumine might not ſtill contain a minute portion of potaſh, as it was prepared by precipitation from alum; the difficulty of procuring perfectly pure alumine in this method being very great, as we ſhall preſently mention. Beſides, as all charcoal contains ſome alkali, this might have aſſiſted in the fuſion, ſo that it is ſtill doubtful whether pure alumine be capable of melting without addition, by any known heat. The other earths promote the fuſibility of alumine when mixed with it. Gerhard found this earth fuſible in a chalk crucible, but not in one of clay; Klaproth found lime to melt in a clay crucible, and not in one of chalk; but it is certain that alumine is one of the moſt refractory in the fire of all bodies in nature, and hence its uſe in its natural clayey mixtures in forming crucibles, furnaces, and veſſels for reſiſting fire, and containing other bodies to be expoſed to heat.

Fuſed with alkalies it does not run into a clear glaſs like the other earths, but forms an opake, puffy, white, ſemivitreſcent, paſty enamel. So Klaproth found the corundum, in which the alumine is about 84 per cent. fuſe with its own weight of carbonated ſoda in an intenſe heat, into an opaleſcent, greeniſh white hard glaſs. (For further particulars on the vitrification of earthy mixtures ſee the article GLASS.)

Alumine is ſoluble in moſt of the acids, with more or leſs facility, and *without effervescence*, unleſs newly precipitated from a ſolution, and ſtill retaining a portion of carbonated alkali, which it does with conſiderable force.

For a complete ſolution, the aſſiſtance of heat is generally required, unleſs it be effected by double decompoſition, as where acetited alumine is formed by adding acetited lead to alum. This earth is much more ſoluble when in its plaſtic ſtate than after it has been heated, and moſt of all, immediately after precipitation from its ſolution, either in an alkali or an acid. The particular ſalts are deſcribed under the article *Alum*, and the reſpective acids.

Alumine diſſolves with eaſe in the pure fixed alkalies, and even in ammonia if newly precipitated. If alumine in this fine ſtate of diviſion be put into three or four times its weight of a ſolution of potaſh, and heat applied, it diſſolves like wax in oil, and by ſlow evaporation dries into rhomboidal pieces. Even the hardeſt aluminous ſtones, ſuch as the CORUNDUM, yield to fuſion with alkali with particular management. This ſolution lets fall the alumine when ſaturated with any acid, an exceſs of which redilſolves the precipitate. Muriated ammonia alſo ſeparates the earth from the alkaline ſolution by complicated affinity, the potaſh uniting with the muriatic acid, and the ammonia thus expelled determining the precipitation of the alumine, which when properly edulcorated and dried is now perfectly pure. [c]

The affinity which the earths exerciſe for each other is a ſubject of the higheſt importance in chemical experiment, as it affects the reſult of the analyſis of almoſt every mineral which has been hitherto examined; and late obſervations have thrown ſo much light on this queſtion as (on ſome accounts unfortunately) to render unſatisfactory the labours of many eminent and excellent chemiſts, whoſe names have long carried with them the higheſt authority. We ſhall therefore compare the characteriſtic properties, and give the proofs of affinity of alumine with each of the other earths ſeparately,

[c] Chenevix. Ph. Tr. 1802.

to assist the reader in the arduous task of chemical analysis.

In many circumstances alumine resembles silex so strongly as to have been frequently mistaken for it: in hardness, the aluminous gems surpass even that of rock crystal; both earths are soluble in fixed alkali, precipitable thence by an acid, resoluble in a slight excess of acid; and when in strong aggregation, the aluminous earth resists the solvent power of acids as completely as the siliceous. The most conspicuous difference between them as they occur in analysis is the following. Silex when redissolved by excess of acid (the muriatic for example) after being first precipitated by it from its alkaline solution, is entirely again separated by the application of heat, and by evaporation nearly to dryness, and then the earth remains insoluble on any future application of acid. Alumine, on the other hand, though the solution has been evaporated to dryness (if not otherwise decomposed by heat), remains again soluble on affusing fresh acid, and thus may be completely separated from the silex. To illustrate this, take two portions of a solution of silex in potash, the one concentrated, the other largely diluted; add to each an acid more than sufficient to saturate the alkali; in the former solution, much of the earth will be visibly precipitated, and again redissolved in the excess of acid; in the latter, because dilute, the same change will take place, but no turbidness will be visible. Then evaporate the solutions nearly to dryness, and a puffy coagulum will be formed in both cases, which is the silex, now no longer soluble, and is left in a state of purity, after due washing, in the form of a fine crystalline sand.

Perform the same process to alumine dissolved in potash, and after evaporation of the muriatic acid, pour on the earth some dilute sulphuric acid, boil for a short time, and a sulphat of alumine will be formed, which, on the addition of a little potash, or sulphat of potash, or acetite of potash, or any other salt containing this alkali, will give numerous crystals, which may easily be recognised for alum.

In another method the two earths may often be conveniently distinguished. Silex fused with as little as half its weight of dry carbonated soda, either in a crucible or before the blow-pipe, effervesces strongly, and at last forms a perfect transparent glass.

Alumine on the contrary does not froth, unites with the alkali with greater difficulty, and forms only an opake, half-fused, whitish enamel.

By the above methods these two earths may be distinguished; the following facts shew their affinity, and will serve to warn the analytical chemist of the occasional difficulty of complete separation of the two. Klaproth found on analysing the Bengal corundum, that proceeding in the usual method of fusing with potash, dissolving the mass in muriatic acid, and evaporation, the silex was so strongly united with the large proportion of alumine as not to be precipitated in a gelatinous form by evaporation of the muriatic solution, as silex generally is, but remained in union with it till the alumine was prepared by solution in sulphuric acid and evaporation, for yielding alum in crystals. The silex then at last was separated, and assumed the gelatinous consistence peculiar to it under such a precipitation, and Klaproth further observed the coagulated silex in a short time to break into several separate unconnected figures in the shape of longish pyramids. When silicited potash is mixed with aluminized potash, the union contracted between the two earths is so great as for a time equally to resist entire separation by the common re-agents, as the same excellent chemist has also remarked.[a]

When once coagulated to a jelly, if diluted with water and heated, the silex appears in purity as a white incohesive granular powder.

Mr. Chenevix[b] also brings as a proof of the affinity of silex and alumine, that when fusing the mixture with potash, if the silex much predominates, a light flocculent siliceous earth appears, which is insoluble in muriatic acid; but if alumine much prevails, no such precipitate is found.

Magnesia is found to exercise even a greater affinity for alumine than silex, and hence it has long been a difficult problem in analysis to find a simple method of entirely separating them. We owe to Mr. Chenevix some very curious facts on this subject, introduced in his analysis of some of the magnesian earths, and first published in the volume of Annales de Chimie above quoted. Magnesia, when unaccompanied by any other earth, and dissolved in an acid, is well known to be only partially precipitated by ammonia, however in excess, the remaining liquor being a soluble ammoniaco-magnesian salt: but if both alumine and magnesia are dissolved in the same acid, the first effect of ammonia is to precipitate entirely the alumine, and in intimate combination with it, a larger portion of magnesia than the ammonia would separate in the former case; and it is only till

[a] Klaproth, An. Essays, p. 68.

[b] An. Chim. tom. 28. p. 203.

the alumine has carried down with it what may be conſidered as its ſaturating doſe of magneſia, that a further addition of ammonia begins to form the ammoniaco-magneſian ſalt, if any magneſia ſtill remains in the ſolution. The like takes place when the precipitant is an alkaline carbonat fully ſaturated with carbonic acid. Magneſia when alone, is firſt precipitated by it and then rediſſolved by the carbonic acid; but when in the ſame ſolution with alumine, both earths are entirely precipitated, and the magneſia is not again diſſolved except it is in greater quantity than to ſatisfy the affinity of alumine.

On the other hand, alumine, when alone, is entirely precipitated from its acid ſolutions by cauſtic potaſh or ſoda, and again re-ſoluble by an exceſs of theſe alkalies; but if accompanied with magneſia, the power of reſolubility is loſt, except with regard to that portion of the alumine which exceeds the ſaturating affinity of magneſia.

Mr. Chenevix gives three modes of ſeparating theſe two earths; firſt, by the malic acid, which, with magneſia, forms a deliqueſcent ſalt, and with alumine, one almoſt inſoluble, ſo that alcohol will diſſolve out only the malat of magneſia. This acid when native is preſerved with difficulty, as it is not cryſtallizable, and mingled with a mucilage very apt to alter in keeping; but it is formed immediately by oxygenized muriatic acid and ſugar, and though not unmixed in this method, the muriatic or acetous acids which remain in the ſolution, will, if properly managed, hardly touch the alumine. A ſecond method of ſeparating alumine and magneſia, is by ſulphuretted hydrogen gas, which alſo forms a ſoluble hydro-ſulphuret of magneſia, and does not touch the alumine: a third mode is by the pruſſic acid, which in like manner takes the magneſia, and leaves the other; both theſe reagents may be added in combination, that is, as an alkaline ſulphuret, or pruſſiat. The malic acid is in one reſpect a preferable teſt to the two others, where there is iron in the mixed aluminous and magneſian ſolution; the malat of iron being very ſoluble, but the pruſſiat and hydroſulphuret ſcarcely at all, ſo that with the malic acid the alumine is left uncombined by the firſt operation.

M. Vauquelin makes a ſimilar obſervation to the above in a ſubſequent paper, on analyſis [c] in general; and remarks that in a mixed acid ſolution of alumine, lime, and magneſia, the addition of *pure* ammonia to ſeparate the alumine ſingly is liable to error, owing to the affinity above-mentioned, which determines the precipitation of magneſia (and lime alſo) along with the alumine: but if every thing is firſt precipitated by a carbonated alkali, the magneſia and lime will become carbonated in preference to any union with alumine; which laſt may afterwards be alone diſſolved by cauſtic potaſh.

To ſeparate alumine from magneſia, and alſo from lime and barytes, Bergman in his valuable memoir on the earth of gems recommends, after ſeparating the ſilex in the way before deſcribed, to digeſt the mixed earths for an hour in ſix parts of cold acetous acid, which, he ſays, will not touch the alumine, but will diſſolve the other earths. This is true to a conſiderable extent, but not perfectly accurate.

Klaproth ſeparates theſe earths, when only theſe are preſent, by diſſolving each in ſulphuric acid, adding ſufficient potaſh to convert the ſulphat of alumine into alum, evaporating to dryneſs, and ſtrongly igniting them for half an hour, and afterwards adding water: the ſulphat of magneſia alone will now be ſoluble, and the alum only on the addition of freſh acid.

Lime ſhews alſo a certain degree of affinity for alumine, though not ſo powerful as magneſia. It is generally known to be a teſt of lime not to be precipitable from its acid ſolutions by ammonia; but Vauquelin has obſerved that this does not entirely hold true when lime and alumine are united in the ſame ſolution, part of the lime being then precipitable by ammonia, owing to the mutual affinity of theſe two earths. Mr. Chenevix alſo remarks, that when lime and alumine are boiled with potaſh, more of the lime is diſſolved than the mere water of the liquid would take up ſingly; and as the alkali has no ſolitary action on lime, its ſolution in this caſe is a proof of its affinity with alumine.

Therefore the method uſually adopted in analyſis, of ſeparating lime from the other earths (namely, after the ſilex is got rid of, firſt to precipitate the other earths and the iron from the acid ſolution by ammonia, with a view of leaving the lime in the liquid,) is not entirely accurate, ſince ſome of the lime will accompany the precipitate; ſo that it is a ſurer way to precipitate the whole by a carbonated alkali, after which the alumine may be taken out by potaſh which will not touch the lime now carbonated.

Barytes and ſtrontian alſo ſhew an affinity for alumine. M. Vauquelin [d] boiled together in water a mixture of ſtrontian and pure alumine, newly prepared and ſtill moiſt. Part was diſ-

[c] An. Ch. tom. 30.

[d] An. Chim. tom. 29.

ſolved, but much left untouched. The ſolution would not cryſtallize by cooling as it does commonly, though much more ſtrontian was uſed than requiſite to ſaturate the water; and the ſolution ſaturated with muriatic acid gave a flocculent precipitate of alumine. On the other hand the undiſſolved maſs was an intimate mixture of the two earths. Thus therefore alumine renders a large portion of ſtrontian inſoluble in water, and is itſelf partly diſſolved in water by help of that ſmall portion of ſtrontian which preſerves its property of ſolubility. Probably if the proportion of the two earths was exactly taken, according to their mutual affinity, none of the ſtrontian would be diſſolved.

Barytes was found to act preciſely in the ſame method as ſtrontian in this reſpect; and the ſmaller the proportion of the barytes, the leſs is the quantity of alumine diſſolved. Beſides, if hot ſaturated barytic-water be added to liquid muriated alumine, the mixed earth is precipitated, and again rediſſolved entirely by an exceſs of the barytes—a very ſtriking reſemblance to the action of alkali.

No very deciſive affinity is ſhewn in analyſis between alumine and oxyd of iron, though it is ſometimes attended with ſome trouble to ſeparate them completely. This is generally done by potaſh, which diſſolves the alumine and leaves the iron; or if the earth ſtill retains a portion of the metallic oxyd, recourſe may be had to pruſſiat of potaſh, the two being firſt diſſolved in an acid.

From all that has been ſaid on the affinities of alumine, it may be imagined how difficult it is to procure this earth abſolutely in a ſtate of purity.

Pure alumine may be prepared either by precipitation from alum, or from the finer clays or aluminous earths. Each method has ſome particular advantages, but in each ſome precautions muſt be taken to enſure its efficacy.

In alum, the only earth is that which is intended to be obtained, which is a conſiderable advantage, but the affinity of this earth, both for ſulphuric acid and for potaſh, is at leaſt as great as that which it ſhews for the other earths, and accurate experiments have ſhewn that a ſingle precipitation from alum can ſcarcely ever be depended on to obtain the earth abſolutely pure. Ammonia, either pure or carbonated, is a better precipitant than potaſh, as the volatile alkali is completely driven off by heat. Berthollet found,[e] however, that alumine precipitated from alum, even by pure ammonia, and well edulcorated, ſtill contained a ſmall portion of ſulphuric acid, as was proved by affording a ſulphuret when ſtrongly heated with combuſtible matter. He therefore recommends, that the firſt precipitate from alum, by ammonia, be rediſſolved in nitric acid, purified from ſulphuric acid by nitrated barytes, and again precipitated by the ſame alkali; and, after due edulcoration, dried in a heat ſufficient to expel the ammonia, whereby the earth is now obtained pure.

Lampadius[f] gives the following method, which is perhaps the beſt that can be adopted for a ſingle precipitation. Diſſolve two ounces of alum in thirty-two ounces of warm water, add a ſmall quantity of pruſſiat of potaſh, and let it ſtand for a day to ſeparate the iron, (a very proper precaution with moſt kinds of alum); then add ſufficient pure ammonia to precipitate the greater part of the earth, but not the whole, by about a fifth or ſixth, by which means the ſulphat of potaſh remains in the mother liquor; after which, dry in a moderate heat to expel the water and ammonia that adhere, and the earth will in general be very pure.

A more economical mode, though by double precipitation, is the following, which, if carefully followed, will anſwer very well Diſſolve the alum, as in the laſt proceſs, and ſeparate the iron in the ſame way. Then precipitate the earth by carbonated potaſh, edulcorate well, and when the precipitate has dried a little into a cohefive maſs, the filtration may be aſſiſted by preſſing gently in a fine cloth; then rediſſolve it, before it is quite dry, in muriatic or nitric acid; purify by nitrat or muriat of barytes, from ſulphuric acid, adding no more of the barytic ſolution than is barely neceſſary; and again precipitate the filtered aluminous ſolution by carbonated or pure ammonia; after which, waſh and dry as before.

Alumine may be alſo obtained pure from its ſolution in potaſh, by adding muriated ammonia, as recommended by Mr. Chenevix, or ſimply by any acid of which the laſt portions may be entirely expelled by heat, if any ſhould adhere to the precipitated earth, ſuch as the acetous or nitric; or as M. Vauquelin adviſes, by ſuperſaturating with muriatic acid, ſo as to make a clear muriatic ſolution, and afterwards precipitating by carbonated ammonia.

Alumine is known to be free from ſulphuric acid when a nitrated or muriated ſolution of it mixes uniformly with nitrated or muriated barytes, without precipitation. It is free from potaſh when, diſſolved by ſulphuric acid (being

[e] An. Chim. tom. 32. [f] Handb. zur Chem. Analyſe.

previouſly ignited to ſeparate any ammonia), it becomes by evaporation nearly to dryneſs, an unctuous-looking maſs, without giving any cryſtals of alum by repoſe for a day; as potaſh or ammonia are abſolutely requiſite to the formation of alum.

Alumine has a ſtrong affinity for the vegetable and animal oils. Alum in ſolution, mixed with ſoap-water, curdles it completely, and the coagulum is an intimate union of this earth with the oil of the ſoap, forming a ſoft flexible maſs, which, when dry, remains ſupple; is inſoluble in alcohol, and, after fuſion, becomes tranſparent. [g]

The attraction of clay of every kind for oil is ſhewn in the valuable cleanſing powder called CIMOLITE, and the different kinds of FULLER'S EARTH.

The affinities of alumine for the acids are in the following order, [h] viz. ſulphuric, nitric, muriatic, oxalic, arſenic, fluoric, ſebacic, tartareous, ſuccinic, mucous, citric, phoſphoric, formic, lactic, benzoic, acetous, boracic, ſulphureous, nitrous, carbonic, pruſſic.

AMADOU. A combuſtible preparation, applied to the ſame uſes on the Continent as tinder is among us. It is made chiefly in Germany, whence it is imported in large quantities to France. The baſis of the amadou conſiſts of the large ſpungy boleti that are found on the trunks of old oaks, aſhes, and various other kinds of timber trees. As ſoon as gathered, they are boiled in plain water, to extract all the peculiar juices; this being done they are dried, and then well beaten with a wooden mallet, in order to render them ſoft: they are alſo by this means ſtretched, ſo as to be reduced to the thickneſs of ſtrong buff leather. A boiling hot ſolution of nitre is now prepared, in which the boleti are immerſed for a ſhort time; they are then taken out, drained, and finally dried in an oven. Good amadou is of a yellowiſh brown colour; is ſoft to the touch like the fineſt felt, perfectly pliable, tough, and ſomewhat elaſtic. It takes fire like tinder, by a ſpark from the colliſion of a flint and ſteel, and burns ſlowly, but is very difficult to extinguiſh. [a]

AMALGAM, is a name given to the combinations of the other metals with MERCURY, which ſee.

AMALGAM *Native*. See SILVER, ores of.

AMBER. *Bernſtein*, Germ. *Succin*, *Carabé*, *Ambre Jaune*, Fr. *Electrum*, *Succinum*, Lat.

M. Werner deſcribes two varieties of amber, differing from each other in colour and tranſparency, but as there is no other perceptible diſtinction, we ſhall follow the example of moſt authors, and treat of amber as a ſingle ſpecies.

The colour of this mineral is generally ſome ſhade of yellow, mixed more or leſs with reddiſh brown; it is found alſo occaſionally green or yellowiſh white: it is uſually tranſparent or ſemi-tranſparent, but when of a green or whitiſh colour it is nearly opaque. The luſtre of the cleareſt kinds is very conſiderable; it is eaſily broken, and exhibits a perfectly conchoidal fracture, may be ſcratched by a knife with great eaſe, but cannot be marked by the nail. Its ſpecific gravity varies from 1.078 to 1.1. It is found in nodules and rounded maſſes, from the ſize of coarſe ſand to that of a man's head, pieces of this latter magnitude are however extremely rare.

Amber occurs in detached pieces on the ſouthern coaſt of the Baltic, on the eaſtern ſhores of England, and in ſmall quantity upon thoſe of Sicily and the Adriatic ſea. It is occaſionally found in the gravel beds near London, and near Siſteron, in Provence: in all theſe ſituations, however, it is merely an alluvial product, caſually mixed with rounded pebbles. The only proper mines of this ſubſtance that have yet been diſcovered, are in Ducal Pruſſia, near the ſea coaſt; theſe, in the reign of Frederic William, were examined by Hoffman, from whoſe account we have ſelected the following particulars.

The uppermoſt ſtratum is ſand, underneath which lies a bed of clay, fifteen or ſixteen feet in thickneſs; to this ſucceeds a ſtratum of trees, in ſome places forty or fifty feet thick, in a half decompoſed ſtate, impregnated with martial pyrites and bitumen, and of a blackiſh brown colour. In this ſtratum are occaſionally found pieces of wood penetrated by veins of amber. The mineralized wood reſts upon a bed of pyrites and ſulphat of iron, among which are not unfrequently found ſtalactites of amber, adhering by one extremity to the under ſide of the trunks of the trees. Beneath the pyrites is a bed of coarſe ſand, in which is unbedded the principal part of the amber, in the form of rounded detached nodules, weighing ſometimes from three to five pounds. The largeſt maſs of amber that was ever diſcovered was met with incidentally, near the ſurface of the ground in Lithuania, about twelve miles from the Baltic ſea: it weighs above eighteen pounds, and is

[g] Berthollet Mem. Sci. 1780. [h] Thompſon's Syſtem of Chim. [a] Encyclopedie Arts & Metiers. art. Amadou.

now in the King's cabinet at Berlin. [a] The amber-mines are worked in the usual way by shafts and galleries to the depth of about a hundred feet. From these circumstances it appears sufficiently plain that amber originates from vegetable juices, probably of the terebinthinate kinds, which are gradually modified by the action of sulphuric acid. As a proof that the change, though considerable, has not been effected with violence, specimens of amber are not unfrequently met with, containing insects, which are generally supposed to be ants, but which, according to Bernard de Jussieu, are exotic insects, not natives of the European continent. [b]

When amber was in greater request as an ornament than it is now, great attention was paid to it by the German artists, and many experiments were made to remove its defects or improve its beauty. The coarser and smaller pieces were called *schlug*, and were principally employed for distillation; those that were a little larger and cleaner were made into varnish, and the best and largest pieces were fashioned into various ornaments, such as snuff-boxes, cane-heads, necklaces, &c. Of the transparent ambers, the bright golden yellow was the most esteemed; of the opaque varieties, the flaky or the scaly. Methods were discovered, especially by Gottlieb Samuelsson, of Breslaw, of rendering opaque amber transparent, and of tinging it red, blue, green and white. Most of these secrets have perished with their inventors, but the two following were the general methods of rendering amber transparent. First, by surrounding it with sand in an iron pot, and cementing it in a gentle heat for forty hours, some small pieces being occasionally taken out to judge of the progress of the operation. Secondly, which was the usual method, by digesting and boiling the amber for about twenty hours in rape-seed oil, by which it became both cleaner and harder; amber thus clarified, however, is much less electric than when in its natural state. [c]

Thales, one of the Greek philosophers, appears to have been the first person who discovered that amber when rubbed had the property of attracting straws, hairs and other light bodies; on which account he ascribed a kind of life to it. A number of analogous and connected phenomena have been added in modern times to this discovery of Thales, and the science hence resulting has been called *Electricity*, from ἤλεκτρον, the Greek name for amber. From the attracting property and real beauty of this mineral, it was held in high estimation among the Romans, who made it into bracelets, and other articles of female ornament: those pieces that contained insects were then, as at present, the most valued. The superior lustre and hardness of gems, and the imitations of them in glass, have thrown amber ornaments entirely into disuse in Europe, though it still keeps up its value in Turkey and the East.

There are two substances that are liable to be confounded with amber, namely, COPAL and HONEYSTONE (Honigstein); they may be readily distinguished, however, by attention to the following properties. Copal is somewhat softer than amber, and when set on fire melts into drops, which amber does not. Honey-stone possesses a much weaker degree of electricity, and when laid on a hot coal, after a short time, gives out a smoke without any flame, and becomes white, without much sensible diminution of size.

Amber, during pulverization, gives out a slight not unpleasant odour, which becomes much stronger when the mass is heated or melted. It cannot be brought to a fluid state without a commencement of decomposition, and the volatilization of part of its acid: at a little higher temperature, if exposed to the air, it takes fire, and burns with a yellowish flame, mingled with blue and green, exhaling a dense pungent aromatic smoke; a light shining black coal is left behind, which with some difficulty is reducible to ashes. The proportion of residue varies considerably: from half a pound of amber, M. Bourdelin obtained, in one instance, $4\frac{1}{2}$ grains of ashes, and in another 12 grains. [d]

Water, whether cold or hot, has no effect on amber. Alcohol by long digestion, or still better by repeated distillation from finely pulverized amber, dissolves a small portion, and becomes of a deep reddish-brown colour, forming the *Tincture of Amber*. On the addition of a little water, the liquor turns opaque and milky, and a resinous matter is at length deposited. The efficacy of alcohol as a solvent of amber depends greatly on its purity, proof spirit having scarcely any action on this substance.

Levigated amber, by slow digestion with an equal weight of caustic potash dissolved in water, combines into a thick saponaceous mass, which is readily soluble both in water and spirit of wine; with the latter it forms the *Tincture*

[a] Tilloch's Journ. v. xviii. p. 93. [b] Tingry on Varnishes, v. i. p. 30. [c] Rees's New Cycloped. art. Amber.
[d] Mem. de l'Acad. des Sciences, 1742, p. 192.

Succini tartarizata, once an article of repute in the Materia Medica. According to Jacobi,[e] the aqueous solution of amber and potash deposits, by slow evaporation, needle-form crystals, of a bitterish taste.

Neither the expressed nor volatile oils have any action on amber by common digestion, except this latter has been previously roasted or melted: when this is the case it is readily soluble in both kinds of oil, either separate or mixed, forming the base of the Amber VARNISHES. Hoffmann however found, that if one part of pulverized amber was put into a glass vessel, with two parts of oil of almonds, and the whole inclosed in a Papin's digester filled with water, the oil and amber in a short time united into a jelly-like mass. Ether has some action, though but slight, on amber.

Amber is unalterable by the weaker and diluted acids. When heated, however, with concentrated sulphuric acid, it is converted into a dark coloured resinous mass, at the same time that a quantity of volatile sulphureous acid is disengaged. Nitric acid attacks amber with great rapidity, accompanied by a very copious production of nitrous gas, and converts it into a light pulverulent resin, entirely soluble in dilute nitrous acid. If pounded amber is thrown into melted nitre, a considerable detonation takes place, and the residue is a greyish saline mass, which when dissolved in water, and subjected to spontaneous evaporation, deposits a soft slimy substance, mixed with slender prismatic crystals, consisting probably of the acid of amber combined with potash. The experiment appears to have been first made by Bourdelin, who, because the salt caused a precipitate with nitrat of silver, and emitted a white vapour with sulphuric acid, supposed it to be muriat of potash: if, however, the nitre which he used was pure, it is difficult to conceive how the muriatic acid could exist in the residue of the process. At all events it is a point worthy of being cleared up.

When amber is exposed to dry distillation in closed vessels, it swells, puffs up, and discharges a large quantity of carbonic acid and carburetted hydrogen: together with these gasses there comes over, first, a colourless empyreumatic watery fluid, with a peculiar, not disagreeable, odour, and containing a little acetous acid; this is called spirit of amber, *spiritus succini*: next follows a thin clear yellowish oil, smelling like petroleum, partly mixed with, and partly holding in solution, a crystalline salt, the *acid of amber*, or *succinic acid:* as the distillation goes on, the oil becomes more coloured and of a thicker consistence, so that towards the end of the process, it is almost black and somewhat viscid. There remains in the retort an intensely black, shining coal, which is employed as the basis of the finest black varnish.

The *oil of amber* is separated from the acid with which it is mixed in the first distillation by washing with warm water, and may be further purified by subsequent rectification; the best method of effecting which is to distil the oil by a very gentle heat, having previously mixed it with a dilute solution of carbonated soda, in order to detain the acid. Carbonated potash, provided it is perfectly neutralized, will answer as well as soda, but if either alkali is at all caustic, the oil will be acted upon, and its quantity considerably diminished. The proportion of oil varies a little, according to the purity of the amber employed, but upon the average amounts, according to Neuman, to nearly two-thirds of the weight of the amber. The oil of amber is only used medicinally as an ingredient in EAU DE LUCE, which see.

We shall conclude this article with an account of the acid of amber or SUCCINIC ACID.

It has been already mentioned that the Succinic acid rises during the destructive distillation of amber, partly in the form of spicular crystals which attach themselves to the neck of the retort, and in part is dissolved in the volatile oil which rises at the same time. The acid in this state is of a dark yellowish brown colour, being contaminated by the oil, and requires successive rectification before it can be obtained tolerably pure. Two methods have been practiced of purifying the acid: the first is, to mix the brown concrete acid with sand, or still better with dry unburnt white clay, free from calcareous earth, and proceed to sublimation by a very gentle heat; the clay detains the most part of the oil, and the acid rises to the upper part of the vessel, where it forms light-brown needle-shaped crystals. The second, and more economical way, recommended by Pott,[f] is first to wash the oil in warm water, in order to separate the acid held by it in solution; then after pouring off the oil to add the solid acid, and heat the water till the whole of it is dissolved; a filter of cotton wool moistened with oil of amber being now prepared, the hot solution is run through it; the oil is principally detained by the filter, and the fluid as it cools deposits long slender crystals of succinic acid, which may be

[e] Act. Acad. Nat. Curios. v. ii. p. 243.

[f] Mem. de l'Acad. des Sciences, 1753.

rendered ſtill purer by ſubſequent ſolution and filtration, or ſtill more effectually according to Lowitz,[g] by the following method; make a ſaturated ſolution of the ſolid acid in hot water, and add a quantity of finely pulverized freſh burnt charcoal, equal to half the weight of the acid: ſtrain the ſolution through a filter of charcoal powder, and as the liquor cools the acid will be depoſited in long, clear, perfectly colourleſs cryſtals.

According to the German chemiſts, the proportion of acid yielded by amber is about one thirtieth of its weight; the French on the other hand, have not in general been able to obtain more than one ſixtieth.

Purified ſuccinic acid is very acid to the taſte, though not corroſive: in very cold water it is ſcarcely at all ſoluble, requiring from 24 to 30 times its weight of this fluid at 50° Fahr. for its ſolution, of boiling water however three parts are ſufficient. The form of its cryſtals is that of truncated three-ſided priſms, or, when prepared in the manner recommended by Lowitz, of thin four-ſided tables. A gentle heat is ſufficient to volatilize this ſalt; it riſes in white vapours like carbonated ammonia. It is neither effloreſcent nor deliqueſcent when expoſed to the air.

The baſe of ſuccinic acid is a compound combuſtible one like the vegetable acids: it burns when expoſed to the blow-pipe, detonates with nitre, and when ſuccinat of potaſh is heated in cloſe veſſels, a large quantity of carburetted hydrogen is given out, and carbonated potaſh mixed with charcoal is left behind.[g]

Boiling alcohol diſſolves ſuccinic acid in the proportion of 117 grains to an ounce, which is almoſt wholly depoſited as the liquor grows cold. If the impure acid is diſſolved in alcohol, and ſix times the quantity of cold water is added, the mixture becomes turbid and milky from the ſeparation of the oil, and if in this ſtate it is thrown upon a filter, a clear fluid holding the acid in ſolution paſſes through, and the oil remains behind on the filter.

Nitric acid diſſolves the ſuccinic acid, but does not convert it into oxalic acid, as was ſuppoſed by Weſtrumb.

Potaſh combines readily with ſuccinic acid, forming a neutral ſalt.

Succinat of potaſh, cryſtallizing in truncated trihedral priſms, which are ſomewhat deliqueſcent in the air, are readily ſoluble in water, have a bitteriſh ſaline taſte, and decrepitate on hot coals. Its acid is deſtroyed by heat, leaving the alkali in a carbonated ſtate.

Succinat of ſoda differs from the former ſalt, in being permanent in the air, and leſs ſoluble in water.

Succinat of ammonia forms needle-ſhaped cryſtals of a ſharp ſaline bitter taſte: it may be volatilized and ſublimed without decompoſition. The fixed alkalies diſengage the ammonia, and unite with the acid.

Succinic acid with lime and barytes forms ſalts of difficult ſolution in water. It unites with magneſia into a gummy uncryſtallizable maſs.

The affinities of ſuccinic acid have not been determined with any accuracy on account of the difficulty of obtaining it pure, for any mixture of oil with the acid will greatly modify its action on other ſalts. According to Morveau,[h] barytes has the moſt powerful attraction for ſuccinic acid, after which come lime, the fixed alkalies, ammonia, and magneſia.

Gren[i] arranges the affinities of ſuccinic acid in the following manner: it decompoſes in the moiſt way all the carbonated alkalies and earths.

All the earthy and alkaline ſuccinats are decompoſed by ſulphuric acid.

The alkaline ſuccinats are alſo decompoſed by nitric, and muriatic, and fluoric acids, but nitrats, muriats, and fluats of lime and barytes, are decompoſed by ſuccinic acid.

The boracic, benzoic, and acetic acids, are inferior in affinity to the ſuccinic acid.

AMBERGRIS (or *Grey Amber*, as it is ſometimes called) is a grey, brittle, light inflammable amorphous ſubſtance, generally found floating on the ſurface of the ocean, or thrown on ſhore in all the ſouthern ſeas frequented by the ſpermaceti whale. It is alſo occaſionally met with in the inteſtine of the ſame animal, which circumſtance, along with the corroborating teſtimony of whale-fiſhers, has very ſatisfactorily cleared up all the doubts that have been entertained as to the origin of this ſingular ſubſtance.

Ambergris is ſometimes found in very large maſſes. The very accurate and faithful Neumann, in his elaborate hiſtory of Ambergris, publiſhed in the Philoſophical Tranſactions for 1734, mentions a celebrated maſs of ambergris thrown on ſhore on the iſland of Tidor, and purchaſed of the king of that iſland by the Dutch Eaſt India Company in 1693, for eleven thouſand dollars, which weighed 182 lb. and

[g] Crells Chem. Annalen. 1793. vol. i. p. 32.
[h] Journ. de Phy. vol. xxvi. p. 463.
[g] Grens Syſt. Handbuch, vol. iii. p. 22.
[i] Syſt. Handbuch.

meaſured 5 feet 8 inches in length, and 2 feet 2 inches in thickneſs. It was long exhibited at Amſterdam, and at laſt broken up and ſold. Other maſſes of many pounds weight have alſo been found floating on the ſea. A captain in the Southern Whale Fiſhery, examined before the privy council in 1791,[a] related that he found 362 ounces of this ſubſtance in the inteſtine of a female whale ſtruck off the coaſt of Guinea; part of it was voided from the rectum on cutting up the blubber, and the remainder was collected within the inteſtinal canal. Dr. Swediaur in his valuable paper on this ſubject,[b] alſo relates many authentic facts to the ſame purpoſe.

The whales that contain ambergris are always lean and ſickly, yield but very little oil, and often ſeem almoſt torpid, ſo that when a ſpermaceti whale has this appearance, and does not dung on being harpooned, the fiſhers generally expect to find ambergris within it. It is uncertain whether this ſubſtance is the cauſe or effect of diſeaſe.

Another convincing proof of the origin of ambergris is, that it generally contains a number of hard bony fragments impacted within it, which are the beaks of the cuttle-fiſh, called by the ſeamen *ſquids*, on which the whale is known to feed, and which are always found mixed with the whale's excrements, more or leſs broken down in the inteſtinal canal.

The phyſical properties of ambergris are the following: its colour is aſh-grey or brown, and ſomewhat mottled; its hardneſs ſufficient to render it eaſily friable, but not to bear a poliſh; when broken down it has a ſoapy feel like ſteatite, and ſhews ſomewhat of a granulated texture. It has ſcarcely any taſte. The ſmell of ambergris when recently taken from the whale, is very ſtrong and rather fetid, but by keeping, the offenſiveneſs goes off, and it acquires a faint muſky odour. When heated or burned it liquefies, and gives that peculiar penetrating fragrant ſmell for which it is ſo much valued, and the ſame takes place when in ſolution or mixed with other ſcents; ſo that, like muſk, it is too powerful for moſt organs till diluted or diffuſed in the air.

The ſpecific gravity is from about .844[c] to .926,[d] ſo that it floats both in ſalt and freſh water.

Several chemiſts have attempted the analyſis of this ſubſtance, among whom are Neumann, Lemery, Hanckwitz, and lately La Grange.

Ambergris begins to melt at about 145°, at 212° it is volatilized in the form of white vapours; if burnt in an open crucible it leaves ſcarcely any ſenſible reſidue; diſtilled in a retort, the products are an acidulous watery vapour, oil, and a concrete ſalt, and a bulky coal is left behind.

From the production of an acid and the excrementitious nature of ambergris, La Grange ſuſpected this acid to be the benzoic. He accordingly treated it both by ſublimation and by boiling with lime, according to Scheele's method of procuring the acid of benzoin, and obtained about a tenth of its weight of this acid ſalt. Water, hot or cold, has no ſenſible effect on ambergris, nor does it extract the acid, as it does partially from gum-benzoin. Acids have but little action on this ſubſtance. The nitric, however, when diſtilled from it, leaves a maſs which dries into a yellow brittle tranſparent reſin.

Cauſtic potaſh forms with it a ſpecies of ſoap, but diſengages no ammonia. The oils, fixed and volatile, diſſolve it without difficulty.

The operation of alcohol on ambergris is the moſt inſtructive. Neumann[e] found that cold ſpirits diſſolved but a ſmall portion of this ſubſtance, but that it was entirely ſoluble in twelve times its weight of tartariſed ſpirit of wine, aſſiſted by a boiling heat, a ſmall earthy reſidue excepted. On cooling and evaporation of the ſpirit a *ſebaceous* matter ſeparates, which Lemery took to be wax, and hence this chemiſt was led to ſuppoſe that ambergris itſelf was a product of bees, an hypotheſis fully refuted by more accurate obſervation. La Grange in the paper above mentioned remarks preciſely the ſame effects in the analyſis by alcohol, and has examined them with more minuteneſs. Ambergris repeatedly digeſted with cold alcohol, yields a browniſh tincture, till every thing ſoluble in this way is extracted. This tincture contains ſufficient benzoic acid to redden litmus, and evaporated to dryneſs leaves a brown brittle reſin, which may be entirely volatilized on hot coals, diffuſing a very fragrant odour. The inſoluble reſidue of the firſt tincture, being now digeſted in freſh ſpirit and heated to boiling, is almoſt entirely diſſolved; but on cooling, the ſpirit depoſits what it had taken up, in the form of a light, bulky maſs, which a little dried, yields to the preſſure of the finger, like curd, ſoftens by heat, and has all the properties of *adipocire*. The trifling reſidue ſtill left undiſſolved, appears to be a carbonaceous matter.

Ambergris is alſo ſoluble in ether.

The following compoſition of ambergris is

[a] Phil. Tranſ. Vol. 81. [b] Phil. Tranſ. Vol. 73. [c] La Grange An. Ch. Tom. 47. [d] Briſſon. [e] Phil. Tranſ. 1734.

given by La Grange, and probably approaches considerably to accuracy. One hundred parts contain

Adipocire - - -	52.
Resin - - - - -	30.
Benzoic acid - -	11.
Carbonaceous residue	5.
	98

The only use of ambergris in this country is in perfumery. The tincture in alcohol, or *essence*, is the preparation chiefly employed. This is of a very brown red when made with tartarised spirit, but brighter coloured when of pure spirit. A drop or two is mixed with a large quantity of lavender water in the shops, and adds much to the fragrance of its scent. It is employed to perfume tooth-powder, wash-balls, hair-powder, &c. It formerly made an article of the Materia Medica, but it is now entirely disused in most parts of Europe, having but little efficacy except in very large doses; when it proves purgative.[f] The chief mart for ambergris is Turkey, Persia, and the East, where it is employed in cookery, medicine, perfumery, and for a purpose never forgotten by oriental nations, as an aphrodisiac, though its virtues in this particular are altogether imaginary.

The price of ambergris is very high. In London it is retailed at from twenty to twenty-four shillings the ounce, and hence its frequent adulteration with wax, benzoin, ladanum, meal, &c. scented with musk. It is not very easy however to imitate it accurately.

AMETHYST, a transparent gem of a violet purple colour, considerably esteemed by the ancients, but less so by the moderns. It is divided by the jewellers into two varieties, the oriental, or purple CORUNDUM, and the common, or purple QUARTZ.

AMIANTH or AMIANTHUS. See ASBEST.

AMIANTHINITE of Kirwan, see STRAHLSTEIN.

AMMONIA, Volatile Alkali. *Alkali fluchtiges*, Germ. *Ammoniaque*, Fr.

The volatile alkali, an agent of high importance in chemistry, is remarkably distinguished from the other alkalies by its great volatility (as its name imports) by its weaker affinity to acids, by its powerful smell, by being only known in the gaseous form when pure, and by being certainly a compound substance.

Ammonia is obtained for actual use only from vegetable and animal substances, more especially the latter; in a few instances that we shall presently mention, it is also formed by the union of its constituent parts in the course of certain chemical experiments. The distillation of animal or vegetable matter has long been known to furnish an ammoniacal product, partly liquid, partly concrete, and capable of being purified by subsequent rectification, which has been termed *salt or spirit of hartshorn*, *spirit of urine*, &c. according to the substance employed.

In all these cases the volatile alkali is disengaged in a carbonated state, and is accordingly strongly effervescent with acids. This subject we shall refer to the articles CARBONAT of *Ammonia*, and ANIMAL *Matter*, and we shall here only describe the properties of ammonia in its pure and caustic state, and the facts which prove its chemical composition. All these facts are comparatively modern; Dr. Black first pointed out the difference between the caustic and mild alkalies, and the respective states of ammonia among the rest. And Dr. Priestley appears to have been the first who obtained this alkali in its purest form, that of a gas, and has termed it, *alkaline air*.

Ammonia is thus prepared: take any quantity of well-burnt lime, slack it with a little water, so as to reduce it to powder, then mix it expeditiously with half its weight of dry muriated ammonia in fine powder. On the instant of mixture, very pungent suffocating fumes of volatile alkali will be disengaged (which should be avoided as they would excoriate the nostrils) and the mixture should be put into a retort of glass or earth, or into an iron or earthen tube, closed at one end, and closely fitted with a stopper, to which a bent glass tube is cemented. On the application of a very moderate heat, by a lamp or a pan of charcoal, the ammoniacal gas will be given off in great abundance for a considerable time, and to be examined chemically must be received in a jar filled with mercury and standing over the same fluid.

In this operation the ammonia is displaced from the muriatic acid by the lime, so that after all the alkali has been expelled, muriat of lime with a great excess of lime remains in the retort. This when duly heated is phosphoric. (See PHOSPHORUS, *Baldwin's*.)

A much smaller quantity of lime is sufficient for the expulsion of the ammonia. Mr. Cornette[a] found by direct experiment that when equal parts of lime and muriated ammonia were used, all the alkali was given out by heat, and in the residue which contained no undecompосed mu-

[f] Swediaur. [a] Mem. de Acad. des Sciences, 1786.

riated ammonia, nearly a fifth of the lime ſtill remained uncombined. On uſing three times the quantity of lime, no more ammonia was obtained than with only equal parts.

Many other ſubſtances will decompoſe muriated ammonia and expel the alkali. The oxyds of lead, minium, and litharge, aſſiſted by heat, may be uſed with advantage, and the reſidue is then muriated lead. Water abſorbs ammoniacal gas with great eaſe, but yields it again when heated to about 130° and hence the liquid ammonia affords a very ready method of furniſhing the gaſeous alkali, nothing more being neceſſary than to put the liquor into a proof bottle with a curved tube, or any ſimilar veſſel, to heat it with the flame of a taper, and to collect the gas over mercury. No greater heat than neceſſary ſhould be uſed, otherwiſe the ſteam of the water driven over along with the gas, will abſorb it again rapidly on cooling.

Ammonia remains a permanent gas unaltered at any known temperature under a red heat. In this ſtate it is intenſely pungent and cauſtic, excoriating the noſtrils when ſnuffed up unmixed, producing a moſt acrid ſenſation to the tongue and a dangerous conſtriction of the larynx. In a dilute form it is gratefully pungent and refreſhing. Small animals immerſed in it are inſtantly killed. The ſpecific gravity of ammonia is not eaſily aſcertained with perfect accuracy, owing to the extreme eaſe with which this gas combines with moiſture in large proportions.

According to Mr. Kirwan's experiments,[b] 100 cubic inches of this gas at 61° temperature, and 30 inches barometrical preſſure, weigh 18. 16 grains. The ſame quantity of common air he eſtimates at 31 grains, and hence the alkaline air is lighter than common air in the proportion of about 6: 10. Therefore as the ſpecific gravity of common air (being 816 times lighter than water) is .0012255, the ſpecific gravity of ammonia is .0007353. Other experiments nearly agree with this eſtimation of alkaline air.

This gas has been commonly repreſented as remarkably dilatable by heat, much more ſo than common air in ſimilar circumſtances. This has been actually obſerved by Prieſtley, Guyton, and other chemiſts, but it appears to apply only to this gas in its *common* ſtate. The experiments of M. du Vernois[c] prove that much of this expanſion by heat is owing to the quantity of water that is vaporized along with the alkali, which quantity being variable, throws an equal irregularity on the reſults. He attempts however to give the following compariſon as an approximation to the truth. 100 cubic inches of common air at 32° and the ſame quantity of ammoniacal gas (procured from dry muriated ammonia and lime) alſo at 32° are reſpectively expanded at different temperatures in the following ratio.

	common air.	ammon. gas.
at 77°	107.89	127.91
122°	125.70	184.87
167	165.74	358.78
212	193.68	680.09

But independently of the error ariſing from the admixture of aqueous vapour, it has been ſuppoſed that even in the heat of boiling water, a ſmall portion of the alkaline gas is decompoſed by the mercury over which it is confined, and which is generally ſlightly oxydated at the ſurface, and we ſhall preſently ſee how readily the metallic oxyds act upon the alkali.

Mr. Gay-Luſſac, in his valuable experiments on the dilatation of gaſſes[d] gives another cauſe of error in the experiments on alkaline air. In receiving the gas *directly* from the mixture of lime and muriated ammonia, he did indeed find it much more dilatable by heat than common air, but on cooling the gas he obſerved it to depoſit a liquid, with cryſtalline points of a ſalt which he took to be either muriat or carbonat of ammonia, all of which again diſappeared on raiſing the temperature. To exclude this impurity he repeated the experiment with ammonia that had previouſly remained in contact with potaſh, and now no longer gave this depoſition on cooling. This gas was now found to expand *exactly in the ſame ratio as common air* by equal increments of heat from the freezing point to 203°.

A high heat decompoſes the alkali as will preſently be ſeen.

Ammoniacal gas extinguiſhes fire. When a lighted taper is plunged into a jar full of this air, it immediately goes out, but juſt before extinction, the flame is enlarged by a kind of halo of a pale yellow colour.[e] The electric ſpark taken in it is red.

Ammonia combines with extreme rapidity with water, the eaſier as the water is colder. Heat is given out at the ſame time. Ice abſorbs this gas with equal facility, and in ſo doing it appears to melt as faſt as if a red hot iron were applied to it. Mr. Davy's experiments on this ſubject are uſeful, and bear the marks of every practicable degree of accuracy.[f]

[b] Eſſay on Phlogiſton. [c] Encyc. Meth. art. Air. [d] An. Chem. tom. 43. [e] Prieſtley. [f] Reſearches.

This chemiſt found that 50 grains of water abſorbed 17 grains of gaſeous ammonia (rather more than a third of its weight, and according to the calculation given above, nearly 463 times its bulk) and by this abſorption the bulk of the liquid was much increaſed, or in other words its ſpecific gravity was diminiſhed. Therefore the levity of ſuch a ſolution is in direct proportion to its ſtrength of alkaline impregnation.

By calculation from two extreme terms Mr. Davy gives the following table of ſpecific gravity of liquid ammonia, correſponding with the reſpective quantities of alkali and water in the ſolution. As this preparation is in conſtant uſe we ſhall give the table, which may be of ſervice in aſcertaining its ſtrength, and regulating the price which it ſhould bear. The temperature is aſſumed to be 52°, but the changes in ſpecific gravity from 40° to 65° are not materially different.

100 parts (by weight) of liquid ammonia of

ſpec. gr.		ammonia.		water.
.9054	contain	25.37	and	74.63
.9166	——	22.07	—	77.93
.9255	——	19.54	—	80.46
.9326	——	17.52	—	82.48
.9385	——	15.88	—	84.12
.9435	——	14.53	—	85.47
.9476	——	13.46	—	86 54
.9513	——	12.40	—	87.60
.9545	——	11.56	—	88.44
.9573	——	10.82	—	89.18
.9597	——	10.17	—	89.83
.9619	——	9.60	—	90.40
.9684	——	9.50	—	90.5
.9639	——	9.09	—	90.91
.9713	——	7.17	—	92.83

Liquid ammonia (the *aqua ammoniæ puræ* of the pharmacopœias) is actually prepared from the ſame materials in two ways; in one, the liquid itſelf is diſtilled; in the other, the gas is received in water and there abſorbed. The former is the oldeſt method, and is ſtill practiſed very largely. It is the following ſlack two pounds of well-burnt quick lime, with one pint of water; when thus reduced to powder, mix it with ſixteen ounces of muriated ammonia, already in powder, put it into a retort, add five pints of cold water, and lute on a receiver, capable of being kept extremely cool, if poſſible ſurrounded with ice. Then diſtil off, with a moderate heat, twenty ounces of the liquid, which will be the liquid ammonia, or cauſtic volatile alkali. It is to be obſerved that the ammonia is ſo much more volatile than water, that the whole of it comes over with the firſt pint or pint and a quarter of water, ſo that no advantage whatever is gained by continuing the diſtillation any longer. The reſt of the water ſerves to keep the reſidue ſufficiently liquid to be readily taken out of the retort. Twice as much lime as neceſſary is employed, but this exceſs ſerves to keep down any carbonic acid that might otherwiſe riſe. The ſpecific gravity of the liquid thus prepared is about .936, and contains about 17 per cent. of ammonia.[g] The proceſs ſhould be conducted ſlowly, and the receiver kept very cool, or elſe the water will again part with the alkali, and this latter, eſcaping in the form of gas, may burſt the veſſels if tight, or run to waſte if open.

The other method, which is neater and probably better in every reſpect, is to receive the gas from the lime and ſal ammoniac, in a known quantity of water, which will abſorb it till ſaturated. No more water, therefore, ſhould be added to the materials than is juſt ſufficient to ſlack the lime, (about half its weight); and to make as ſtrong a ſolution as can conveniently be kept in a ſummer heat, as much water ſhould be employed to abſorb the ammonia as the weight of the muriated ammonia put into the diſtilling veſſel. This laſt, inſtead of a wide neck, ſhould terminate in a bent tube, plunged to the bottom of the water, and an apparatus ſimilar to that of Woulfe's, to prevent abſorption. If the receiving bottle is ſurrounded with ice, the retort may be heated pretty rapidly.

As this liquid ſpeedily abſorbs carbonic acid from the air, it ſhould be kept in well cloſed bottles. The effect of heat upon it has been already mentioned to be the entire expulſion of the ammonia in form of gas, and nothing but pure water is left.

The effect of cold is ſingular. If cooled very low it loſes much of the pungency of its ſmell (the alkali not being then ſo eaſily given off); and at laſt at the temperature of freezing merbury (—40), it begins to cryſtallize in brilliant flexible needles; or if more haſtily cooled to this intenſe degree, or even ſtill lower, it becomes grey, ſemitranſparent like glue, or like ſilex in its gelatinous-precipitate form, and with ſcarcely any ſcent.[h]

Many other liquids will abſorb ammoniacal gas. Alcohol does it with great eaſe, and appears but little altered by it.

We ſhall now relate ſome of the numerous experiments that inconteſtibly prove that am-

[g] Duncan's Edinb. Diſpenſ.

[h] Fourcroy An. Chem. tom. 43.

monia is a compound ſubſtance, which are both analytical and ſynthetical, this alkali being decompoſed in a variety of proceſſes, and in a few, being formed by direct union of its conſtituent parts.

Dr. Prieſtley's experiments[i] are among the firſt in the decompoſition of this alkali. On paſſing the electric ſpark through this gas, he found it to be permanently enlarged after every ſhock, and when water was admitted, juſt ſo much remained unabſorbed as had been added by the exploſions. The air was now ſtrongly inflammable, detonating when mixed with common air, as violently as the inflammable air from metals. The colour of the electric ſpark was red in this air, as in hydrogen. The extent of dilatation, Dr. Prieſtley found to be about three times the original bulk of the ammoniacal gas, and when at its extreme degree, no portion of the electrized air was now abſorbed by water. He afterwards found that mere heat would produce a ſimilar effect, though leſs perfectly, for on paſſing alkaline air through a red hot tube, part of it was changed to inflammable air, and part went through unaltered. Inflammable air, or hydrogen, is therefore thus proved to be one conſtituent of ammonia. The other is detected by the following beautiful and ſimple experiment. Having previouſly found that the oxyds of lead were revived when heated in inflammable air, Dr. Prieſtley tried the ſame with ammoniacal gas, and found that maſſicot (an oxyd of lead) was thereby reduced to reguline lead, with a certain diminution of the air, but not ſo compleat as when hydrogen alone was employed; for the alkaline air, after it would reduce no more of the metal, left a large reſidue, which Dr. Prieſtley, to his ſurprize, found to be *phlogiſticated* or azotic air. Red mercurial oxyd was in like manner reduced in alkaline air; water was generated in a very ſenſible quantity, and the reſidue, as before, was azotic, mixed with ſome oxygen gas from the mercurial oxyd. Theſe experiments of the electrization of ammonia, and of reduction of metallic oxyds, have been confirmed by many other chemiſts.

The partial decompoſition of volatile alkali by metallic oxyds did not eſcape the acute obſervation of Scheele. This eminent chemiſt obſerved[k] that liquid ammonia, when ſuffered to remain in contact with oxyd of manganeſe and nitrous acid, was entirely decompoſed, and furniſhed an elaſtic gas, whilſt the oxyd of manganeſe was ſo far reduced to the metallic ſtate as to become ſoluble in the nitrous acid. The ammonia therefore furniſhed hydrogen to the oxyd, to ſeparate it in the form of water from this metal, and the other part of the ammonia, the azot, eſcaped in a gaſeous form. Acid of arſenic and ammonia were found to undergo a ſimilar change. (See MANGANESE and ARSENIC.)

But the moſt accurate and convincing experiments on this alkali were undertaken by M. Berthollet, on the facts diſcovered by Prieſtley and Scheele. M. Berthollet[l] firſt aſcertained that on the diſtillation of nitrous ammonia more water was produced than belonged to the cryſtallization of the ſalt, and that the ſource of this water was the mutual decompoſition of the acid and the alkali, the former ſupplying the oxygen, and the latter, the hydrogen. See NITRATE OF AMMONIA.)

M. Berthollet alſo repeated the experiment of the reduction of metallic oxyds on ammonia. Oxyd of copper diſſolved in this alkali, evaporated to dryneſs and afterwards ſtrongly heated, became compleatly reduced; water was formed, and azotic gas given out, together with ſome ammonia that had eſcaped decompoſition. Hence M. Berthollet beautifully explained the detonation of fulminating gold, and even confirmed it by actual experiment in cloſe veſſels. This preparation is oxyd of gold combined with ammonia; when heated it detonates vehemently, the gold is reduced, water is ſuddenly formed, and azotic gas given out. (See GOLD-*Fulminating*.)

Another ſingular phenomenon, alſo obſerved by M. Berthollet, is explained by the decompoſition of ammonia. When oxymuriatic acid is mixed with liquid ammonia, a ſtrong effervescence takes place, though the alkali contains no carbonic acid; a gas is given out, and the acid immediately loſes its characteriſtic properties, becoming ſimple muriatic acid. This is beautifully explained by the decompoſition of ammonia, the hydrogen of the alkali uniting with the exceſs of oxygen in the acid into water, and the azot of the alkali appearing uncombined in a gaſeous form, for the effervescing gas when examined is found to be azotic. (See OXYMURIATIC *Acid*.)

A croud of intereſting experiments, ſubſequent to theſe above mentioned, come in confirmation of this hypotheſis of the decompoſition of ammonia. M. Fourcroy, on paſſing the oxymuriatic acid gas[m] into liquid ammonia, obtained a large quantity of azotic gas, which was collected in the pneumatic trough. On adding ammoniacal gas to oxymuriatic gas,[n] a

[i] Expts. on Air, vol. ii [k] Eſſays. [l] Mem. de l'Ac. des Sciences, 1785. [m] An. Chim. tom. x. [n] An. Chim. tom. 4.

white flame was produced, and water was immediately ſeen trickling down the ſides of the veſſel.

The ſame chemiſt has alſo purſued the experiments with ammonia and metallic oxyds.[o] Liquid ammonia added to nitrated mercury in ſolution, precipitates the metal black, and nearly metallic, and azotic gas is given out. The ſame takes place more ſtrikingly with liquid ammonia and the red mercurial oxyd in powder. A ſtrong effervescence of azotic gas takes place, the oxyd turns firſt white, then black, and on being moderately heated becomes moſtly running mercury. The black oxyd of manganeſe moiſtened with ammonia in like manner effervesces ſlightly even at a cold temperature, the metal is partially reduced and becomes grey, and azotic gas is formed.

Nitrated iron treated with ammonia, is equally reduced to the ſtate of the leaſt oxydation, and the precipitate is the black oxyd of iron.

Many of the neutral ammoniacal ſalts when ſtrongly heated, are partly ſublimed and partly decompoſed. The nitrated ammonia has been already mentioned. Mr. Chenevix[p] found that the ſulphated ammonia being diſtilled *per ſe*, gave out firſt, water of cryſtallization, then part of the ſalt ſublimed unaltered, after which came over ſulphureous acid and *azotic gas*, which continued to the end of the proceſs.

The alkali of muriated ammonia, though not eaſily deſtructible by mere heat, is entirely decompoſed by the nitric acid. Mr. Woulfe,[r] by diſtilling one pound of nitric acid from four ounces of muriated ammonia, found the acid to act with great vehemence on the ſalt, and the whole contents of the retort were diſtilled over in a liquid form, in which no trace of undecompoſed ammonia could be detected. The nitric acid was alſo in part decompoſed, and much azotic gas, mixed with ſome oxygen, was given out in the proceſs.

It often happens that in the decompoſition of the alkali, the azot, which is one of the conſtituents of ammonia, inſtead of being given out in the form of gas, enters into new combinations, particularly with oxygen when preſent in exceſs, and forms Nitrous *Acid*. The particulars of this ſingular converſion will be given under this article, but it may be mentioned here, that Dr. Milner produced this acid by paſſing ammonia through heated oxyd of manganeſe; Fourcroy the ſame, by ammonia and ſulphat of mercury; and Prouſt the ſame, by ſtrongly heating a mixture of ammoniacal gas with an exceſs of oxygen. If a ſmaller quantity of oxygen is uſed, the product of the gaſſes, after detonation in a high heat, is merely water and azotic gas.

We have now to mention ſome of the experiments in which ammonia is produced by the mixture of its conſtituent parts.

Animal putrefaction, and the diſorganization of all animal and many vegetable ſubſtances by fire, are proceſſes of this kind, that are perpetually going on, for in neither inſtance can ammonia be traced in the ſubſtance in any notable quantity, before putrefaction or combuſtion. (See Animal *Matter*.) But chemiſtry furniſhes us with more direct experiments.

An ammoniacal ſmell has often been obſerved accidentally by ſeveral chemiſts, where it was not expected; and more particularly in experiments with nitrous gas or acids, and various metallic oxyds. This was noticed by Dr. Prieſtley, in a ſolution of nitrated copper, mixed with iron filings, which had long ſtood together. Mr. Hauſſman, of Colmar,[s] has ſhewn the ſame production of alkali, on mixing nitrous gas with the precipitate from acetite of iron. In this caſe the nitrous gas is rapidly abſorbed by the iron precipitate, and at that time ſuch an interchange of principles takes place, that a ſmall portion of nitrated ammonia is formed in the mixture. On adding lime or cauſtic potaſh, the ammonia is expelled, and becomes ſenſible to the ſmell. A like production of volatile alkali always takes place when the green ſulphat of iron is ſaturated with nitrous gas. This curious fact, which depends on very complicated affinities, will be explained in the article Nitrous *Gas*. It will be ſufficient to obſerve, in this place, that the azot of the ammonia is provided for in the nitrous gas, and the hydrogen in the decompoſed water of the ſolution.

Dr. Auſtin's experiments on the formation of ammonia are highly intereſting.[t] Dr. A. found, that no mixture of the two conſtituents, hydrogen and azot, when both in a gaſeous form, could be brought to unite into ammonia, either by mixture in any proportion, or by any third addition. Even when the two gaſſes were the identical parts of a given quantity of ammonia, decompoſed by electricity, they could not again be re-united in their alkaline form. Dr. A. attributes this, probably with reaſon, to the great difference of ſpecific gravity between the two gaſſes, and hence he was led to attempt an union between the two, by putting

[o] An. Ch. tom. 2. [p] Phil. Tranſ. vol. 86 p. 315. [q] J. Phyſ. tom. 31. [r] J. Phyſ. tom. 31.
[s] J. Phyſ. tom. 30, for 1787. [t] Phil. Tranſ. for 1788.

the hydrogen in contact with azotic gas at the inſtant of its formation, before it had perfectly aſſumed the form of hydrogen gas, or as it is termed in its *naſcent ſtate*. This method ſucceeded. Iron filings, which are known to yield hydrogen ſoon after mixture with water, were moiſtened, and incloſed in an atmoſphere of azotic gas. In about twenty-four hours ammoniacal gas was detected, by the uſual teſt of changing to green a piece of blue-ſtained paper, which was ſuſpended in the veſſel. The green of nitrated copper on paper was alſo changed to blue, by the ſame proceſs, in a few days. The ſame generation of ammonia took place in a few hours, when nitrous gas was ſubſtituted for the azotic. On the other hand the ſame change occurred, though in a longer time, when common air was uſed inſtead of the azotic. Hence it would follow that a ſmall portion of ammonia is always produced whenever iron ruſts in the open air, or generally by every natural proceſs which evolves hydrogen.

We have already mentioned the formation of volatile alkali by nitrous gas, and ſeveral metallic oxyds, and referred the reader to the article nitric acid. In the following ſimple experiment this alkali is produced immediately in a very ſenſible quantity. Pour ſome moderately ſtrong nitrous acid upon an ounce or two of tin filings, ſufficient to moiſten them completely, and ſtir them together; the action will be immediate and vehement, and copious fumes of nitrous gas will ariſe; a very ſhort time afterwards add ſome lime or dry cauſtic alkali, rub them together, and a very pungent ſmell of ammonia will be given out. In this experiment the ammonia which is formed from the decompoſition both of nitrous acid and of water, firſt unites with another part of the acid, forming nitrated ammonia, which might be procured as ſuch from the mixture. Then, on adding the lime, this newly formed ſalt is again decompoſed, and the volatile alkali is expelled in its gaſeous form. Zinc filings, moiſtened with nitrated copper, and mixed with lime, equally give out ammonia.

The method which has been purſued by M. Berthollet, and ſucceeding chemiſts, of aſcertaining the relative proportion of the two ingredients of ammonia (and indeed the only one practicable) has been firſt to reſolve ammoniacal gas into its conſtituent parts, hydrogen and azotic gaſſes (for which electricity offers a certain but tedious agent), and then to abſtract the hydrogen by detonation with oxygen in Volta's eudiometer. The perfect reſolution of the ammonia after electrization over mercury, is known by the enlargement ceaſing, and by the electrized gas being now entirely unabſorbed when water is thrown up to it. In the ſubſequent detonation of the hydrogen (in which an exceſs of oxygen ſhould be employed) a great portion of the gas diſappears; which loſs, as it is accounted for by the production of water, muſt be eſtimated according to the known proportions in which hydrogen and oxygen conſtitute this fluid. The remaining gas (allowing for the exceſs of oxygen employed) is the azot, the other conſtituent of the ammonia. In this manner M. Berthollet eſtimates the compoſition of ammonia to be 121 by weight of azot, and 29 of hydrogen; ſuppoſing too that the comparative ſpecific gravity of the former to the latter is as 11 to 1.

Mr. Davy[u] in his experiments decompoſed his ammonia by tranſmiſſion through a red hot tube of green glaſs; after which he eſtimated the hydrogen and azot in the manner abovementioned, and the reſult coincided almoſt exactly with that of M. Berthollet.

An approximation to the ſame reſult is afforded by calculation from the known ſpecific gravities of all the airs concerned in theſe experiments.[v] According to Mr. Kirwan, 100 cubic inches of alkaline air weigh 18.16 grains, of azotic air weigh 30.535 grains, and of hydrogen gas weigh 2.613 grains. M. Berthollet reckons that 1.7 cubic inches of ammonia, expands by electrization to 3.3, and conſequently 100 cubic inches of the electrized air now weighs only 9.355 grains: and by ſubſequent calculation, Dr. Auſtin found that a mixture of this ſpecific gravity is formed by 121 grains of azot and 32 of hydrogen.

Conſidering the difficulty of obtaining a perfect uniformity in comparative experiments of this nature, in a gas ſo greedy of moiſture as ammonia is, this coincidence is very ſatisfactory, and we may therefore conclude, without danger of conſiderable error, that 100 grains of pure ammonia are compoſed of about 80 grains of azot and 20 of hydrogen.

Ammonia combines with great eaſe with all the acids, forming neutral ſalts, which will be deſcribed under the reſpective acids. Its affinity for acids is weak, compared to that of the other alkalies and many of the earths. It is a remarkable property of this alkali that in many inſtances, when added to earthy or metallic ſalts, where its affinity to the acid is on the whole greater than the baſis already combined, it only partially

[u] Reſearches. [v] Auſtin Ph. Tranſ.

decompoſes them, uniting with the remainder of the ſalt into a triple compound, ſometimes cryſtallizable, conſiſting of the acid, the earth or metallic oxyd, and ammonia. It is of importance to be aware of this in chemical analyſis. The affinity of magneſia, for example, is ſo nearly the ſame as that of ammonia to acids, that ammoniaco-magneſian triple ſalts are conſtantly occurring when the three ſubſtances come together.

The frequent decompoſition of ammonia upon metallic oxyds, reducing them from the higheſt ſtate of oxydation to the loweſt, or even to the reguline ſtate, has already been mentioned, when deſcribing the facts that prove the decompoſition of this alkali. It alſo ſimply diſſolves other metallic oxyds, as copper, cobalt, zinc, nickel, tungſten, &c. Some of theſe compounds are cryſtallizable.

When ammoniacal gas is mixed with ſome of the gaſeous acids, the carbonic or muriatic for example, a moſt beautiful phenomenon occurs: the two gaſſes inſtantly on mixture form a denſe white cloud, totally loſe their gaſeous form, and condenſe into minute flakes of the dry cryſtallized ammoniacal ſalt, ſo that, if pure, not an atom of gas is left in the veſſel in which they are mixed. A rapid and complete abſorption therefore is the conſequence, and this is attended with a very ſenſible evolution of heat. See CARBONAT and MURIAT of ammonia.

This circumſtance affords a very delicate teſt of ammonia, for if any of the alkaline gas is given off from any ſubſtance (ſuppoſe an uncorked bottle of liquid ammonia,) and a glaſs rod, ſtraw, or any thing of the kind be only moiſtened with muriatic or nitrous acid, and held in the ammoniacal atmoſphere, the alkali floating in the air will immediately be detected by the thick white cloud of nitrated or muriated ammonia, which will be ſeen to hover round the acid. This teſt is even more delicate than the ſmell.

The cauſtic powers of the volatile alkali are much inferior to thoſe of the two fixed. It does not readily corrode animal matter. With oil it unites readily to a certain degree, but not ſo firmly and perfectly as the fixed alkalies. (See SOAP *Ammoniacal.*)

Sulphur may be made to combine with ammonia by diſtillation. Some intereſting products are the reſult, which will be deſcribed under the article SULPHURET.

The conſtant tendency of ammonia to aſſume the gaſeous ſtate, in a very moderate heat, forms a conſiderable obſtacle to its union with many bodies with which the fixed alkalies may be made to combine; of courſe there can be no ſuch ſubſtance as an ammoniacal glaſs.

PRUSSIAN *Blue* is one of the moſt curious combinations of ammonia that we are acquainted with.

Ammonia in its cauſtic ſtate is uſed only in medicine and in the laboratory. Ammoniacal gas is one of the beſt correctors to the dangerous ſuffocating properties of the vapour of oxymuriatic, and probably of other acids. In the event of ſuch an accident, the ſpeedieſt method will be to mix quick lime and muriated ammonia with a little water, and to place the veſſel containing it on the floor, as near to the feet of the ſufferer as can be borne with ſecurity, ſo as to allow him to inhale cautiouſly ſome of the aſcending ammoniacal gas, which will be given off in great abundance.

Ammoniacal gas is detected, as we have before mentioned, by giving a denſe white fume with muriatic acid vapour. It is known to be pure when it is totally and inſtantly abſorbed by water. This teſt is in general ſufficient, for the other rapidly abſorbable gaſſes are the aeriform acids, which cannot remain in a gaſeous ſtate along with ammonia. If a ſmall admixture of ſulphuretted hydrogen gas be ſuſpected, the teſt of acetited lead may be uſed, which will be blackened by water that has abſorbed this gas, but not by liquid ammonia. The ſolution of ammonia in water is known to be perfectly deprived of carbonic acid when it gives no effervescence with acids, no cloudineſs on mixture with ſtrong alcohol, and particularly when it does not alter the tranſparency of a ſolution of pure lime (calcareous ſpar or Carrara marble) in the nitrous, muriatic, or acetic acids. This laſt, which is a moſt delicate teſt, ſhould be made in a well corked bottle, for though pure ammonia will not precipitate lime, carbonated ammonia will do it very readily, and the alkali, if expoſed to the air, will ſpeedily abſorb from it ſufficient carbonic acid to render this teſt fallacious. If muriated ammonia is accidentally mixed with liquid ammonia in the proceſs of diſtillation, the preſence of the muriatic acid is thus detected: ſaturate part of the liquor with pure diſtilled vinegar, and add to it a few drops of nitrated ſilver, a white precipitate of luna cornea will then indicate the muriatic acid, for nitrated ſilver is not clouded by pure acetited ammonia. We may add, that in the analyſis of any ſubſtance ſuppoſed to contain an ammoniacal ſalt, this alkali is beſt expelled by adding lime to the ſubſtance to be analyſed, and

diſtilling the whole in a cloſe veſſel. The whole of the ammonia then comes over with the very firſt products, and if condenſed by a little water in a cool receiver, it is thus obtained in a concentrated ſtate, convenient for further examination. An example of this method is given in the analyſis of ALUM.

The affinities of ammonia are the ſame as thoſe of POTASH and Soda in the moiſt way, but the tendency of the volatile alkali to gaſification on the application of heat, is ſo ſtrong as to throw ſome uncertainty on its relative affinities, even at a moderately elevated temperature.

AMMONIURET. This term has been uſed of late to expreſs the ſolution of any ſubſtance in ammonia, as *Ammoniuret of copper, of cobalt*, &c.

AMNIOS, *Liquor of the—Liquor Amnii.* Is the fluid contained within the membranes of the fœtus of viviparous animals before birth. The unborn animal floats freely in the liquor amnii, and is therefore always in contact with it, till the time of parturition, when the membranes containing it are broken and the fluid eſcapes. It appears to be ſecreted by the inner ſurface of the membrane itſelf, and phyſiologiſts have not been able to aſcertain, with much probability, any other uſe for it than to afford a protection to the fœtus from external injury whilſt in the womb, and a convenient medium in which the incipient animal may grow and encreaſe without confinement.

The more obvious chemical properties of the liquor of the amnios have been noticed by ſeveral writers: we are indebted to Meſſrs. Buniva and Vauquelin for a conſiderably minute analyſis of this liquor, both human and from the cow, which appear to differ eſſentially in character. [a]

The human liquor amnii is ſlightly ſaline to the taſte, and ſomewhat turbid in appearance, owing to the ſuſpenſion of a kind of caſeous matter, which is probably the ſame that adheres to the ſkin of new-born infants. This liquor froths by agitation, is heavier than water, its ſpecific gravity being 1.005, and when heated becomes ſomewhat opake, like milk much diluted with water. The analyſis by reagents, and by evaporation, preſents nothing particularly intereſting. By far the greater part is mere water, the other ingredients amounting to no more than $\frac{1}{12000}$ of the whole, and of this a part is albumen, together with muriat of ſoda, phoſphat of lime, and a ſmall exceſs of ſoda. In conſequence of this laſt circumſtance, it is found to give a green to tincture of violets, and yet it ſlightly reddens tincture of litmus, as if an acid were preſent in exceſs, but the latter teſt appears not always ſo certain as the former. The liquor becomes ſlightly putrid by long keeping.

The liquor amnii of the cow differs from the human in being ſlightly red, having an acid taſte with ſome bitterneſs, a ſmell ſimilar to vegetable extract, a greater denſity, being 1.028 in ſpecific gravity, and much more viſcid.

Examined chemically, it ſtrongly reddens tincture of litmus, gives a copious precipitate with muriated barytes, and an abundant red precipitate with alcohol. Evaporated, a thick ſcum ſeparates, which on cooling is covered with white cryſtalline blades, and when reduced to about a fourth of its bulk and cooled, much of this cryſtalline matter is collected, and appears to be a concrete acid, differing from the other known ſubſtances of this claſs, and has been termed by the diſcoverers the *amniotic acid*. It may be alſo obtained in a purer ſtate by evaporating the whole liquor to a very thick conſiſtence, and treating the reſidue with boiling alcohol, ſucceſſively added. On evaporating the ſpirit the acid is left pure. A thick pitch-like ſubſtance remains untouched by the alcohol, which is an animal extract ſomewhat peculiar. It has a very ſingular undeſcribable taſte, is very ſoluble in water, and cauſes it to froth on agitation. This property, together with its inſolubility in alcohol, gives this extract a reſemblance to animal gelly, but it differs in not combining with tannin. When burned it gives ammonia, an empyreumatic oil, a pruſſic acid, and leaves a bulky coal, eaſy to burn, which furniſhes a white aſh, containing the phoſphats of magneſia and lime.

The liquor amnii likewiſe contains ſulphat of ſoda, which is ſeparated from it in regular cryſtals when the evaporation is carried to a ſyrupy conſiſtence. It may alſo be obtained by calcining the entire reſidue and ſubſequent lixiviation.

The amniotic acid above mentioned is a concrete white cryſtalline ſubſtance, ſomewhat ſour to the taſte, reddening litmus, ſoluble ſparingly in cold water, abundantly in hot water, but moſtly cryſtallizing again on cooling. It readily unites with the alkalies when cauſtic, and the ſalt thence reſulting is much more ſoluble in water than the acid ſingly. The other acids again ſeparate it from its alkaline combinations, in the form of a white ſhining powder. It does

[a] An. Chim. tom. 33.

not decompoſe, except heated, the alkaline carbonates. It has no ſenſible effect on the ſolutions of ſilver, lead, or mercury. On calcination it ſwells, and gives out a ſmell of ammonia mixed with that of the pruſſic acid. Though it agrees with ſome other of the cryſtallizable acids in many of its properties, it does not correſpond in all with any one of them, ſo that at preſent it muſt be conſidered as a peculiar acid. Azot is one of its conſtituent parts, as it furniſhes ammonia by heat. The quantity hitherto examined has been very ſmall, as it is contained in the liquor of the amnios, but ſparingly.

AMPHIBOLE of Hauy. See HORNBLENDE.

AMPHIGENE of Hauy. See LEUCIT.

AMYGDALOID. See MANDELSTEIN.

ANALCIME of Hauy. See ZEOLITE.

ANALYSIS is the ſeparation of any ſubſtance into its component parts, with the view of aſcertaining their nature, relative proportion, and mode of union. As every operation in chemiſtry is attended with a diſunion of parts, the formation of new compounds is almoſt an invariable conſequence; and hence the buſineſs of analyſis is intimately connected with the whole of chemical ſcience, and can only be thoroughly underſtood by one who is well verſed in every branch of chemiſtry. Hence it becomes impracticable to draw up preciſe rules for every circumſtance of analyſis in leſs compaſs than would include the whole of operative chemiſtry, but we may allow ourſelves ſome obſervations on the ſpecific objects to be attained in conducting theſe proceſſes, and the general principles on which they are to be purſued.

It would appear incredible that ſuch an infinite variety of ſubſtances, all differing from each other both in phyſical and chemical properties, ſhould be produced from a very few ſimple ſubſtances, if we did not know that every compound of elementary parts acquires by its union new properties which did not belong to either of its conſtituents taken ſeparately. Hence a compound once formed, perpetually acquires the powers of an element, in being again able to unite, undecompoſed, with other bodies, ſimple or compounded, in various proportions; and thus to produce new ſubſtances, in which the conſtituents often retain their original affinities, and in analyſis again ſeparate into their firſt elementary combinations. Thus the cryſtallized ſalt, nitrat of ammonia, is compoſed of nitric acid, ammonia, and water, each of which is itſelf compound, but in this particular combination acts as an elementary body.

For nitric acid conſiſts of azot and oxygen,
ammonia —— of azot and hydrogen,
and water —— of oxygen & hydrogen;
ſo that the elements of nitrated ammonia are ſimply azot, hydrogen, and oxygen; but it is requiſite that they ſhould firſt be combined into the acid, alkali and water, before this ſpecific neutral ſalt can be formed.

The buſineſs of chemical analyſis is to reſolve a body into its conſtituent parts, but it is always an individual queſtion belonging to every proceſs of analyſis, to determine whether this reſolution ſhould proceed to entire ſeparation into real elements, or only into thoſe compounds which act the part of intermediate elements, that is, whether disjunction or diſorganization be required: as for example in the inſtance before us, whether nitrated ammonia be reſolved into azot, hydrogen, and oxygen, or into nitric acid, ammonia and water. The former mode of analyſis is in general the beſt calculated for experimental reſearch, the latter for utility; but, however, a mixture of the two methods is commonly adopted, where the proportion and nature of the compound produced has already been fully aſcertained by previous experiment.

Hence the infinite importance of accurate tables of the compoſition of all the pro-elementary ſubſtances uſually met with, as by them we are enabled to ſimplify analyſis, and to reduce it to much greater certainty. When we already know the compoſition of water, of ammonia, of the acids, of neutral or metallic ſalts, and the like, we may be ſatisfied with bringing the reſults of our analytical experiments to this point, and may deduce the reſt from our tables; if we know that a hundred parts of luna cornea, dried at a certain heat, always contain ſeventy-five parts of ſilver, we may calculate on this proportion of metal, and ſave the further trouble of reduction. This mode of proceeding, however, requires conſiderable caution.

The moſt rigid proof of the accuracy of analyſis is by *ſyntheſis*, or by again producing the ſame compound, on uniting the identical parts which we have given as its conſtituents. It is but ſeldom that we are able to exhibit this proof in a perfectly ſatisfactory manner; we may oftener, however, reproduce a ſubſtance reſembling that which we have analyſed, by employing *ſimilar* conſtituents, if not the *identical* ſubſtances. But even this proof is almoſt totally wanting in the analyſis of the organized vegetable or animal matters, eſpecially when reduced to their ultimate elements, and generally when only ſeparated into their immediate conſtituents.

One of the moſt important agents in analyſis is *heat* or *fire*, and even in ſome inſtances it is the only agent required. *Electricity* often appears to operate in analyſis in nearly the ſame manner as fire. Thus ammonia is equally decompoſed by the electric ſpark and by ignition; hydrogen and oxygen by both are united into water. In the Appendix we ſhall deſcribe the kinds of APPARATUS particularly adapted to the moſt accurate analytical experiments. We may here enumerate, the burning lens for applying ſolar heat; the ſimple and elegant apparatus, conſiſting of a tube paſſed through a furnace, whereby ſubſtances are ignited without contact with the burning fuel; the electro-chemical apparatus; and the beautiful contrivance of Woulfe, for detaining ſeparately the products of diſtillation, together with the pneumatic apparatus for gaſeous ſubſtances.

The other great operation in analyſis is the application of *reagents*, or ſubſtances which indicate the parts of the body to be examined, either by diſſolving a portion if ſolid, or by ſeparating a portion from its ſolution, if already in a liquid ſtate, or by producing ſuch changes of colour, ſmell or ſenſible properties, as are previouſly known to belong only to certain chemical compounds.

The particular precautions to be obſerved in the ſteps of chemical analyſis differ ſo much, and the very mode of proceeding depends ſo entirely on the apparent nature and quality of the ſubſtance to be analyſed, that it would be a fruitleſs taſk to collect under one head all that is to be ſaid on this moſt extenſive ſubject. We ſhall therefore refer the reader to the individual ſubſtance, as for example to *indigo*, where the methods of analyzing this dye are required, and alſo to the following articles.

The analyſis of minerals, which has been more aſſiduouſly cultivated than perhaps any other branch of analytical chemiſtry, includes the examination of metallic ores, and of the other products of the mineral kingdom. But as the preciſe portion of metal ſufficient to conſtitute a mineral a metallic ore, is unknown before analyſis, and when known cannot be accurately laid down (the term *ore* being often uſed in a technical ſenſe, to imply a proportion of metal worth the extraction in the large way); and as moſt minerals ſhew ſome trace of metalline ingredients, we ſhall refer the whole ſubject of the analyſis of ſolid bodies belonging to the mineral kingdom to the article MINERALS, *Analyſis of*.

The ſubject of *Mineral* WATERS we ſhall treat ſeparately.

The analyſis of GASSES requires a peculiar apparatus and appropriate precautions.

The leading characters that diſtinguiſh ANIMAL and VEGETABLE matter will be enumerated under their reſpective heads, and may aſſiſt the practical chemiſt in determining to which of theſe great claſſes the ſubſtance which he is analyſing may belong.

ANATASE. *Schorl-bleu* of R. De Liſle. *Oiſanite* of Lametherie. *Octaedrite* of Sauſſure.

The colour of this mineral is for the moſt part ſteel-grey, which in certain directions paſſes into blackiſh or reddiſh-brown: it alſo occurs occaſionally of a bright indigo-blue. It is found cryſtallized in lengthened octahedrons, the ſummits of which are ſometimes truncated; the lateral faces are ſlightly ſtriated acroſs: the cryſtals are ſmall, and often ſo minute that their form is ſcarcely to be recognized by the naked eye. The luſtre of the anataſe is very brilliant, between the metallic and vitreous: its fracture preſents lamellæ, parallel to the four faces of the octahedron and to the baſe. It is commonly opaque, ſeldom tranſlucid, very rarely ſemi-tranſparent. It is hard, brittle, difficult to break: ſpecific gravity 3.85.

The anataſe is not fuſible, *per ſe*, before the blow-pipe: when heated with an equal weight of borax it fuſes into a glaſs of an emerald green, which as it cools cryſtallizes in needles. By a further addition of borax, the reſult is a tranſparent glaſs of a hyacinth red: if this glaſs is heated gradually, at the extremity of the cone of flame produced by the blow-pipe, it becomes opaque and of a deep blue colour; by a continuance of the heat the blue changes to white, and in a higher temperature, the bright tranſparent hyacinthine colour again makes its appearance. Theſe ſucceſſive changes may be renewed at pleaſure, as was firſt obſerved by M. Eſmark.

The only ſubſtance with which the anataſe is likely to be confounded is blende, but beſides that the form and ſtructure of theſe two ſubſtances are very different; it may be remarked that blende is incapable of ſcratching glaſs, which anataſe will do very readily.

No accurate analyſis of this mineral has yet been made; but Vauquelin has aſcertained that its principal ingredient is oxyd of titanium.

The anataſe is found at Vaujani, near Allemont, in Dauphiné, on the mountains near the town of Oiſans. It lines the cavities of a vein that

traverſes a primitive rock, and is accompanied by minute cryſtals of quartz and ſelſpar. [a]

ANIMAL MATTER. The antient diviſion of terreſtrial bodies into animal, vegetable, and mineral, applies with much more propriety to natural hiſtory than to chemiſtry: in the former ſcience it furniſhes a ſtable and uſeful baſis for claſſification; in the latter it is at beſt ambiguous, and liable to miſlead.

Several of the moſt important chemical elements are found ſometimes in different, ſometimes in the ſame combinations, in all the three kingdoms of nature, and therefore cannot with propriety be claſſified under any individual.

However, it is not unimportant to diſtinguiſh, as far as may readily be done, the *proximate* conſtituents of each natural claſs, and more frequent combinations which are met with by the chemiſt.

We may alſo obſerve here that almoſt all the diſcoveries relating to the chemiſtry of animal bodies are due to modern philoſophers, and take their date from the period at which the analyſis of gaſeous bodies began to aſſume a regular ſcientific form. Many curious and valuable experiments are indeed to be met with before that period, and ſeveral intereſting ſubſtances, ſuch as phoſphorus, pruſſic acid, ammonia, &c. were known to poſſeſs an animal origin; but the real nature of theſe bodies, the mode of their exiſtence and their combinations, were yet undiſcovered. An infinite labour yet remains in this department of chemiſtry, and the reſearch is the more difficult as it demands the aſſiſtance of extenſive knowledge in anatomy, phyſiology, and in the ſtructure and the functions of animals; and as all the poſſible operations of the chemiſt, in his laboratory, appear to bear little if any analogy with thoſe that occur in organized living bodies.

The preſent ſtate of animal chemiſtry includes the analyſis which has been made of the various animal ſolids and fluids; the chemico-phyſiological enquiries which have been inſtituted concerning the living functions; the changes produced by diſeaſe; thoſe which take place after death; and ſeveral miſcellaneous facts relating to the uſe of certain parts of animals in the arts, in medicine, &c.

Scarcely any arrangement will uſefully include all the conſtituent parts of animal bodies, as in chemical properties they paſs into each other by inſenſible gradations, and by apparently ſlight differences in the proportions of their elements. Still leſs will any arrangement, ſatisfactory to the chemiſt, anſwer the purpoſes of phyſiology, or coincide with the diſtribution and mutual connexion of the animal functions. We ſhall content ourſelves with enumerating the principal parts of animals, in the order which appears the moſt natural, and indicating the heads under which their chemical properties will be deſcribed.

The principal elementary ſolids of the body are the following; *muſcle* or *fleſh*, in which reſides the power of motion, voluntary or involuntary, and in chemical properties differing from any other organ. *Cellular membrane* or *web*, (the tela celluloſa of phyſiologiſts,) a fine network, which forms the great connecting medium between the different organs, and anſwers an infinite variety of purpoſes of ſupport, connexion and union: when condenſed it forms the various *Membranes* or ſheathings, *Tendons*, *Ligaments*, and on the ſurface of the body the true *Skin*. The chemical analyſis of all theſe parts is conſiderably ſimilar, regard being had to the age and nature of the animal, &c.—*Brain*, a peculiar chemical compound.—*Bone*, diſtinguiſhed for the large proportion of earth and earthy ſalt; teeth, horn, and cartilage belong to this claſs.—The *Tegument* of animals, either for warmth or protection from external injury, to this belong the *Cuticle*, *Nail*, *Hair*, *Feather*, *Wool*, and many of the calcareous coverings or habitations of animals; *Shell*, *Coral*, &c. Some reſemblance in chemical properties is found between the different kinds of ſoft and hard teguments reſpectively.

Of the animal fluids, the moſt important in every point of view is the *Blood*, that fluid from which every other part of the animal is formed, and which therefore muſt contain the elements of every thing animal that is met with. The analyſis of this fluid is complicated and peculiar. The only ſubſtance approaching to it in properties appear to be the *Chyle*. *Milk* is unqueſtionably the next in intereſt, and its analyſis has long been familiar to chemiſts. A great number of fluids might be termed *lymphatic*, or ſuch as conſiſt chiefly of water, holding in ſolution only a very minute portion of animal and ſaline matter. The *Perſpiration*, the liquor which moiſtens the cavities of the body, the *Amnios*, the *Tears*, perhaps the *Saliva* and *Pancreatic Juice* are of this ſpecies. A more animalized lymph, diſtinguiſhed by a greater degree of viſcidity, is the *Mucus* of the noſe, bronchia, the *Synovia*, &c.

The *Bile*, a ſpecies of animal ſoap much

[a] Hauy traité de Min. vol. iii. p. 129. Mineralogie de Brochant. vol. ii. p. 548.

compounded, is a very peculiar fluid. *Animal Oil*, under the various names of *Fat*, *Tallow*, *Suet*, *Marrow*, &c. forms a diſtinct claſs. To this perhaps may be added, though conſiderably differing in chemical properties, *Wax* and *Spermaceti*. No animal fluid has occupied more attention than the *Urine*, even from the earlieſt times of animal chemiſtry.

Beſides the foregoing ſubſtances, there are many others which have a place in the hiſtory of the analyſis of animal matter, and cannot be eaſily arranged under any general head. Of this kind are muſk, caſtor, ambergris, &c. which will be found under their reſpective titles.

The chief proximate conſtituent parts of the above-mentioned animal ſubſtances are: *Water*, which appears to enter ſimply as water into the compoſition of all the ſolids, to give flexibility and elaſticity to the moving and yielding parts, and to form by far the greater part of all the fluids, oil excepted: *Fibrin*, alſo called *Gluten*, found in the blood, and the chief conſtituent of muſcular fleſh: *Albumen*, much reſembling fibrin in chemical properties: *Gelatin* or *Jelly*: *Oil*: a ſpecies of *Reſin*: one or two peculiar *Acids*: ſome alkaline and earthy ſalts, chiefly *Soda* and *Lime*, with the *phoſphoric* and *muriatic* acids: and alſo a ſmall portion of *Iron*.

The analyſis of all kinds of animal matter preſents a certain ſimilarity of reſult which very ſatisfactorily coincides with the ſmall number of elements into which the above proximate conſtituents are reſolvable. It ſhews that Azot, Hydrogen, Oxygen, and Carbon, perform the leading parts in the innumerable changes by which every animal ſubſtance is elaborated in the living organs; but the diſorganization of theſe by chemical means gives riſe to certain compounds not to be found in the original body.

The analyſis by fire was principally reſorted to by the older chemiſts, and though leſs diſcriminative than the uſe of reagents, it is highly inſtructive. All the hard, the ſoft, and the fluid parts of animals (the latter being previouſly evaporated nearly to dryneſs) if put into a retort without addition, and heated firſt ſlowly and afterwards to ignition, exhibit nearly the following appearances:[a] a watery fluid firſt clear, afterwards brown and turbid, diſtills over: this contains ſome ammoniacal ſalts, and ſoon after *carbonat of ammonia* comes over, part of which diſſolves in the liquor, and part cryſtallizes on the neck and ſides of the receiver. To this ſucceeds an oil, at firſt nearly limpid, but ſoon coloured, thick and fœtid. This oil is accompanied with more carbonat of ammonia partly cryſtalline, in part diſſolved in the oily vapour. At the ſame time a quantity, often very large, of gas paſſes over, which is found to be chiefly carbonic acid, but fœtid on account of its mixture with the empyreumatic oil, and mixed with carburetted hydrogen, and ſometimes ſulphuretted or phoſphuretted hydrogen. When nothing more is given over, and the retort is red hot, if the proceſs is ſtopped, a ſhining black coal is found, very difficult to burn to aſhes, and mixed with the phoſphat of lime, and other fixed matter which the ſubſtance contained. The chief products therefore of animal matter diſtilled without addition, are water, carbonat of ammonia, animal oil, carbonic acid gas, and a reſidue of coal with fixed earthy ſalts. But of theſe products ſcarcely one is found in this preciſe combination in the animal ſubſtance before diſtillation; they are therefore *formed* out of their elements by the action of fire, and hence the confuſion and uncertainty attending the analyſis of theſe bodies before the nature of water, of carbonic acid, of ammonia, and of hydrogen, was underſtood. Of theſe products, the volatile alkali is the moſt important, for it is generated in abundance by many changes to which animal bodies are expoſed, and is not to be detected except in minute quantities, before theſe changes have taken place. In the article ammonia, we have fully ſhewn the compoſition of this alkali to be azot and hydrogen, and hence it becomes requiſite in accounting for the generation of ammonia, to prove the exiſtence of its two conſtituent elements in animal matter. The preſence of hydrogen is obvious, from the quantity of water exiſting in all animal ſubſtances, from the production of oil by diſtillation, and the actual evolution of much hydrogen in a gaſeous form, mixed with carbonic acid. The preſence of the azot has been demonſtrated in an equally ſatisfactory and very ingenious manner, eſpecially by the valuable reſearches of M. Berthollet.

This admirable chemiſt reſorted to the nitric acid as an agent for the decompoſition of animal matter. He found that when ſilk, hair, wool, and other animal ſubſtances were digeſted with nitric acid *with application of heat*, a peculiar oily ſubſtance was produced, and along with it a large quantity of Oxalic *acid*,[b] the particulars of which experiments will be deſcribed under this acid. In a ſubſequent ſeries of experiments,[c] the ſame chemiſt, purſuing the

[a] Fourcroy Syſt. de Conn. Chem. [b] Mem. de l'Acad. des Sciences, 1780. [c] Ibid. 1785.

former ſubject in connection with the compoſition of ammonia, which then engaged his attention, treated a given portion of ſilk with nitrous acid as before, but with an apparatus for collecting the gaſſes that might be produced. He found (as indeed Dr. Prieſtley had done before) that the firſt effect of the acid *before the application of heat*, was to diſengage a very large portion of *azotic gas*. After this, on heating the mixture, much nitrous gas was generated, and oxalic acid was *now* produced. There are therefore two periods of the operation of nitrous acid on animal matter, the firſt, without heat, characterized chiefly by the production of azotic gas; the latter with heat, diſtinguiſhed by the production of oxalic acid and other phenomena, which will be elſewhere noticed. After the firſt period it is alſo found that the nitric acid itſelf is not decompoſed, as it will faturate as much alkali as before: conſequently the azot muſt be generated from the animal ſubſtance.

Though the preſence of azot in animal matter cannot be queſtioned, we poſſeſs no other means of extracting it perfectly in its inſulated form except the one above mentioned, for the elements of animal ſubſtances appear to be peculiarly liable to combination, and among them the azot. The generation of nitric acid is another azotic combination, animal matter being requiſite for the manufacture of ſaltpetre. The relative quantity of azot contained in different animal matters, is therefore in general to be inferred from that of the ammonia which it produces by diſtillation, or by other proceſſes of decompoſition, and ſubſequent experiments with nitric acid, confirm this poſition.

Putrefaction, or the ſpontaneous analyſis of animal matter, performed by warmth and moiſture, though a moſt repulſive proceſs to all the ſenſes, has engaged the attention of ſeveral excellent chemiſts, and the phenomena which it exhibits illuſtrate in a ſtriking manner the other analytical experiments. Under this article it will be ſeen how important are the combinations of azot in this natural proceſs, and how intimately it is connected with the production of ammonia and of nitric acid.

The action of heat and of acids under certain circumſtances alſo generates the Prussic *Acid*, a ſubſtance peculiarly animal and worthy of attention.

The operation of the nitric acid on animal matter has already been mentioned; the ſulphuric acid acts with almoſt equal energy but in a ſomewhat different manner.[d] A piece of fleſh, for example, immerſed in this acid, concentrated, but cold, ſoon becomes coloured ſucceſſively yellow, red, and black, and acquires a paſty conſiſtence: the mixture heats, but gives out no gas, and when examined the acid is found diluted with the water extracted from the fleſh, and alſo in part ſaturated with ammonia and ſoda. The fleſh is charred, and there ſeparates from it a portion of oily matter. The preciſe nature of the change is not entirely underſtood, but the generation of ammonia is indiſputable, as this alkali is found in union with the acid, and could not be previouſly detected in the animal matter. Another ſingular production alſo in this caſe is, the acetous acid, which may be detected by diluting the mixture, filtrating and diſtilling the liquor. The acetous acid riſes in the diſtillation.

The cauſtic fixed alkalies have long been known to act moſt powerfully upon animal matter: when concentrated and eſpecially aſſiſted by heat, they diſſolve indiſcriminately all the ſoft parts into a ſaponaceous pulp. M. Fourcroy has found that ammonia is diſengaged at the time of its action, and that it is *formed* in the proceſs. See Soap, *Animal*.

So much remains to be done on the ſubject of animal chemiſtry, that it might be ſuperfluous to enlarge further on a general head. The collective induſtry of chemiſts however, preſents a very reſpectable maſs of information concerning the properties of a variety of the moſt intereſting ſubſtances belonging to this great claſs of natural bodies, to which individually we ſhall refer our readers.

ANNEAL. When a ſubſtance melted or nearly in a ſtate of fuſion, is cooled very haſtily, its texture is ſo much altered, that, if a ductile metal, it loſes much of its malleability, and cannot be extended far under the hammer without cracking; or, if a brittle metal, a glaſs, or vitreſcent mixture, it is liable to fly to pieces by a very ſlight change of temperature or external injury. To avoid this the proceſs of annealing is reſorted to, which is nothing more than cooling the heated or melted ſubſtance as ſlowly and equally as poſſible, often in a ſeparate furnace of the requiſite heat, and ſometimes called an *annealing oven*. The utility of annealing is ſhewn very conſpicuouſly in the manufacture of *Glaſs*, the caſting of *Speculum Metal*, or the beating of *Gold*.

ANNOTTA, or *Arnotta*, *Roucou*, Fr. *Orlean*. Germ.

Arnotta is a dry hard paſte, browniſh on the

[d] Fourcroy.

outside and red within, brought from Cayenne and various other parts of America, in long rolls of about two or three pounds weight, and much used in Europe in dyeing. This article is procured from the seeds of a large tree, the *Bixa Orleana* of Linnæus, *Roucoyer*, or *Macaw* tree, also called by the Caribs *Achiote*, *Cochehue*, or *Bichet*, and by the Brazilians, *Urucu*. They are thus prepared; the seeds when ripe are gathered, the husk taken off, gently bruized and put into a trough to soak for about eight or ten days, being well stirred twice a day with a wooden implement. They are then beaten with heavy mallets for a quarter of an hour, till they are thoroughly bruised, again moistened with water and passed through a sieve. When thus reduced to a kind of pulp, it is put into a wooden vat, and allowed to ferment or putrify for a week, during which time it gives out a very fetid smell, and moulds on the surface. After this the pulp is again beaten, and soaked with water twice successively.

The seed is now nearly exhausted of its colouring matter, which has passed into the several waters with which it has been washed, and which are carefully reserved, strained through sieves, and mixed in different proportions. This water holding the colouring matter suspended, is then transferred into iron boilers, and heated gradually, till a scum rises to the surface, which is successively removed as it forms into another boiler. This scum is the annotta, and it is slowly dried in the last boiler with perpetual stirring, till it is of so thick a consistence as not to stick to the wetted finger. After this it is laid out on the floor to dry, and made up into cakes, (the negro who does this part of the business smearing his hands with palm oil,) and finally wrapped up in palm leaves, and in two months time it is fit for exportation.

The Caribs make annotta in a much simpler manner. They take the seeds when ripe, and rub them for a long time in their hands smeared with palm oil, till the fine red outer coat of the seed is rubbed off and sticks to the palm of the hand, which is the annotta, and undergoes no other preparation than being moulded into large cakes and dried. This is esteemed the purest, as it has undergone no change by fermentation.

Annotta readily dissolves in water, and more easily in alcohol. Its solutions have a yellowish red, or orange cast. The watery decoction has a strong smell, and an unpleasant rather pungent taste. Alkalies change it to a high orange, and much assist the solution in water. Acids precipitate from the solution an orange sediment, soluble in alkalies. Alum gives a similar precipitate or lake, but of a deeper hue. Sulphat of iron gives an orange brown lake; sulphat of copper a yellowish brown; solutions of tin a lemon coloured.

Annotta is employed in the countries where it grows for various purposes of colouring, for staining the skin, giving a colour and a peculiar taste to certain articles of food, sometimes to chocolate. In Europe it is used largely in dyeing, particularly silks, of different hues of red, orange, aurora, &c. In this case it is always prepared with an alkali, which gives a cast of red. The colour is fugitive, particularly in the sun's light, but it is not readily washed out, and is a very powerful dye, a small quantity giving a tinge to a very large body of liquor.[a]

A peculiar use of annotta is in giving the high orange yellow to Cheshire and Wiltshire cheese, so much in fashion at present. To employ it, the annotta is rubbed on a stone with a little whey, till a sufficiently strong solution is made, which is mixed with the cheese-curd just before pressure.

ANTS, *Acid of*. See Formic Acid.

ANTIMONY. Στιμμι, Gr. *Stibium*, Lat. *Spiesglass*, *Spiesglanz*, Germ. *Antimoine*, Fr. *Proteus*, *Leo ruber*, *Plumbum nigrum*, *Balneum regis*, *Lupus metallorum*, Alchem.

Antimony is a compact brittle metal, of a brilliant slightly bluish-white colour; fusible at a red heat, and by a higher temperature, with exposure to air, wholly convertible into a white vapour. It is soluble in nitro-muriatic acid; and precipitable therefrom in the form of a white powder by distilled water, and of a deep brick red colour by liquid hydrosulphuret of ammonia.

Antimony is found in occasional mixture with the ores of lead, of copper, and of silver; but the six following are the only species which are allowed by mineralogists to rank as the proper ores of this metal.[b]

Sp. I. Native Antimony; *Gediegen Spiesglas*; *Antimoine natif arsenifere* (of Hauy)

The fresh-broken surface of native antimony is of a pure tin-white colour, but by exposure to the air it acquires a slightly greyish or yellowish tinge. It is found in mass, disseminated and kidney-shaped. Its lustre is metallic, very

[a] Berthollet's Art of Dying. Encycl. Method. Arts and Mets. (Art. Roucou.) Leonhardi Wort. (Art. Orléan. &c.)

[b] Brochant Mineralog. vol. ii. p. 369. Hauy Traité de Mineralog. vol. iv. p. 252. Emmerling, vol. iii. Weidenmann, Handbuch, &c. De Lile Cryſtallographie, vol. iii. Kirwan's Mineralogy, vol. ii.

brilliant, even ſpecular. It is compoſed of flat or ſlightly curved plates, and therefore preſents a foliated fracture. It is brittle, and moderately hard, paſſing into tender: its ſpecific gravity has not been aſcertained, but is conſiderable, probably about 6.0.

Antimony when native is by no means in a ſtate of abſolute purity, but always contains a portion of arſenic, varying from two to fifteen per cent. hence it exhales an alliaceous odour when heated before the blow-pipe.

Native antimony was firſt diſcovered in 1748, at Sahlberg, in Sweden, by Schwabe, in a gangue of white calcareous ſpar; and has ſince been found at Allemont, in Dauphiné, by Schreiber, in white quartz. It may be conſidered, however, as a very rare mineral. Arſenical ſilver having a general reſemblance to native antimony, has ſometimes been miſtaken for it; a minute portion, however, expoſed to the blow-pipe, at once ſhows the difference, the latter being wholly evaporable, while the former, after giving out a little arſenical vapour, remains behind, forming a bead of ſilver. The native tellurium of Fatzebay has alſo a conſiderable reſemblance to native antimony, but its colour is not quite ſo white, and before the blow-pipe it decrepitates and volatilizes with a clear ſomewhat browniſh flame.

Sp. II. Grey Sulphuret of Antimony; *Grau Spieſsglas-erz; Antimoine Sulphuré.* (Hauy.)

This ſpecies is divided by the German mineralogiſts into four varieties, the compact, foliated, radiated and plumoſe.

Var. 1. Compact.

The colour of this ſubſtance is lead grey, paſſing into ſteel grey, and tarniſhing blue or purple by expoſure to the air. It occurs in maſs or diſſeminated. Its luſtre is metallic, ſhining or little-ſhining. Its fracture is ſmall grained, uneven. It is tender, eaſily broken, leaves a greyiſh trace when rubbed on paper, and by this means acquires a poliſh. Its ſpecific gravity is conſiderable, but has not been exactly aſcertained. When expoſed to the blowpipe it melts very eaſily, giving out a white vapour and a ſulphureous odour: by a continuance of the heat it is entirely volatilizable. So great is its fuſibility that it will flow when held for a ſhort time in the flame of a candle.

This variety is rarer than any of the following. It is found mixed with other antimonial ores at Braunſdorf, in Saxony; Goldkronach, in Bareith; Majurka, in Hungary; and in Auvergne: it is uſually accompanied by quartz and ſpathoſe iron ore.

Var. 2. Foliated.

This variety differs from the preceding in being of a high ſteel-grey colour, and in preſenting a fine grained foliated fracture. Specific gravity 4.36. It is almoſt always accompanied by quartz, and by the two following varieties. It is found at Gold-kronach, Braunſdorf, Stolberg, in the Hartz and Nagyag in Tranſylvania.

Var. 3. Radiated. (Striated, of Kirwan.)

The recent fracture of this mineral is, like the preceding, of a light ſteel-grey colour; its ſurface, however, preſents a blackiſh grey colour, mixed with azure blue, golden yellow, and other irideſcent tints. It occurs in mamillated, glandular, and ſtalactitic maſſes, or diſſeminated, or cryſtallized. The primitive cryſtalline form of ſulphuretted antimony has not yet been aſcertained; it is, however, eaſily and very neatly diviſible by ſections made parallel to the axes of its priſms. The only regular cryſtals of this mineral are, 1. An oblique angled tetrahedral priſm, terminated by tetrahedral pyramids, with triangular faces, (*Antim: ſulphuré quadriectonal* of Hauy.) 2. The ſame priſms, bevilled at the acute-angled edges, and terminated by tetrahedral pyramids with trapezoidal faces, (*A. S. ſexoctonal* of Hauy.) It alſo occurs in bundled or diverging needles, or in obſcure cylindroids. The ſurface of the cryſtals is always ſtriated longitudinally, and is commonly of a very brilliant metallic luſtre. The internal luſtre is ſometimes much, ſometimes little-ſhining. The fracture is ſtriated, either broad or narrow; radiated, diverging or implicated: when the ſtriæ are very broad, they give almoſt a foliated appearance, and being very brilliant, ſuch ſpecimens have obtained the name of *Specular Antimony*. It flies, when broken, into irregular priſmatic or long-granular fragments; is tender and ſomewhat brittle. Sp. grav. from 4.13 to 4.51. According to the analyſis of Bergman, it conſiſts of 74 antimony and 26 ſulphur, *per cent.* The Hungarian antimony alſo contains a variable proportion of gold.

This variety is the commoneſt of all the antimonial ores. It is procured in Hungary, at Felſobanya, and Kremnitz; at Dravitza, in the Bannat; at Braunſdorf and Rochlitz, in Saxony; at Lubillac, in Auvergne, and at Allemont, in Dauphiné, in France; at Pereta, in Tuſcany; in Cornwall, in England; alſo in Spain, Mexico, and Siberia. The moſt ſplendid irideſcent ſpecimens come principally from Hungary and Auvergne.

It is found for the moſt part in micaceous ſhiſtus and clay porphyry, mixed with pyrites

and oxyds of iron. Its gangue in Hungary is ſulphated barytes, but elſewhere quartz; or, rarely, calcareous ſpar, fluor ſpar, or chalcedony.

Var. 4. Plumoſe. (*Federerz: Antim. ſulph. argiſentifére* of Hauy.)

Its colour is ſteel-grey, paſſing into greyiſh black, lead or ſmoak-grey; by expoſure to the air it tarniſhes to an irideſcent blue or yellow. It occurs in minute capillary cryſtals, inveſting the ſurface of other minerals with a delicate down or wool; the cryſtals are often ſcarcely viſible to the naked eye, and ſo interlaced as to appear like an amorphous cruſt. The external luſtre of this mineral is ſemi-metallic, little-ſhining. Its fracture is confuſedly fibrous. It is very tender, almoſt friable. Sp. grav. 3.57.

Before the blowpipe it emits a ſmoak that depoſits a white and yellow powder on the charcoal, and the reſiduum melts into a black ſlag. It has not yet been accurately analyſed, but according to Bergman conſiſts of antimony, iron, arſenic, ſulphur, and ſometimes ſilver. The proportion of the laſt ingredient is very variable, never exceeding 4 *per cent.* it is therefore improperly ranked by ſome mineralogiſts among the ſilver ores.

It is upon the whole a mineral of rare occurrence, and is found chiefly at Freyberg and Braunſdorf, in Saxony; and at Stollberg, in the Hartz; alſo at Schemnitz, in Hungary. It is accompanied by quartz, calcareous ſpar, brown ſpar, galena, martial pyrites, and blende.

Sp. III. Red Antimony. *Roth Spiesglas erz. Antimoine hydroſulphuré* of Hauy.

The colour of this mineral is a cherry red, more or leſs deep, paſſing on the ſurface into brown, reddiſh, or bluiſh. It occurs ſometimes maſſive or diſſeminated, but moſt commonly in minute capillary cryſtals, either radiating or implicated. Its luſtre is little ſhining, vitreous; its fracture is fine and irregularly fibrous. It is opaque, brittle, almoſt friable: ſp. grav. 4 to 4.7.

It melts eaſily before the blowpipe and evaporates, giving out at the ſame time a feeble ſulphureous odour. Red antimony has ſometimes been confounded with the red ſilky oxyd of copper: this latter, however, is of a brighter red colour, and diſſolves with effervescence in nitrous acid, communicating to the ſolution a green tinge; the antimonial ore, on the contrary, is inſoluble in nitrous acid, and by the action of this fluid is covered ſuperficially with a white cruſt. No accurate analyſis has yet been made of this mineral: it was formerly ſuppoſed, on account of its colour, to contain arſenic and ſulphuretted antimony; according to Sage it is a native kermes, or hydroſulphuret of antimony: thus much, however, is certain, that it occurs in the crevices and inveſting the ſurface of the common grey ſulphuret of antimony, and appears to originate from this by the proceſs of ſpontaneous decompoſition: the amorphous or maſſive variety is frequently ſtudded with octahedrons of native ſulphur.

It is found at Braunſdorf, in Saxony; Malazka and Kremnitz, in Hungary; and Allemont, in Dauphiné.

Sp. IV. White Antimony. Muriated A. of Kirwan; *Weiſs Spiesglaſerz; Antimoine oxydé* of Hauy.

The colour of this mineral varies from ſnow-white or yellowiſh white to greyiſh and aſh-grey. It is found rarely in maſs; more frequently in the form of ſtars or diverging needles, upon the ſurface of other ſubſtances; alſo cryſtallized, in the form of tables, with four rectangular faces, or cubes, or tetrahedral priſms, which are accumulated together in bundles or cells. The ſurface of the cryſtals is ſmooth, or longitudinally ſtriated and very brilliant. The fracture is ſtrait-foliated, exhibiting a bright vitreous luſtre, paſſing into the pearly. It is tranſlucid, brittle, tender and heavy.

In entire cryſtals it decrepitates before the blowpipe, but when pulverized it melts quietly and without difficulty, giving out a white vapour, and by degrees entirely evaporates. Between two coals it may be reduced to the metallic ſtate. The tabular cryſtals, according to Klaproth, are compoſed of oxyd of antimony with muriatic acid. The needle-ſhaped variety from Dauphiné, has been analyſed by Vauquelin, and appears to contain

86	oxyd of antimony,
3	oxyd of iron and oxyd of antimony,
8	ſilex,
97	
3	loſs
100	

White Antimony is an extremely rare mineral: the tabular kind is principally found at Przibram, in Bohemia, on the ſurface of galena; the fibrous variety comes from the mountain Chalanches, near Allemont, in Dauphiné. It is probable, however, that two diſtinct ſpecies are confounded together under the appellation White Antimony; the one being muriat of Antimony in tabular cryſtals, from Bohemia; the other being oxyd of Antimony, in bundled fibres, from Allemont

Sp. V. Antimonial Ochre; *Spiesglas okker; L'ochre d'Antimoine* of Brochant.

The colour of this subſtance is ſtraw or lemon yellow, paſſing to yellowiſh grey. It occurs in maſs, diſſeminated, or inveſting; it is without luſtre, has a fine earthy fracture, is ſoft, heavy, and brittle.

Before the blowpipe it becomes white, and volatilizes without melting; it effervefces when fuſed with borax, and is in part reduced to the metallic ſtate. It has not yet been analyſed, but is ſuppoſed by Karſten to be an oxyd of Antimony. It occurs in ſmall quantities at Braunſdorf, in Saxony, and in Hungary, mixed with grey and red Antimony.

Sp. VI. Yellow Antimony; *Gelb ſpieſglas erz; La mine d'Antimoine jaune* of Brochant.

The colour of this mineral is orange or wax-yellow, or yellowiſh white, often becoming duſky by expoſure to the air. It is found cryſtallized in ſtriated interlaced needle-ſhaped priſms, or in quadrilateral tables: it is ſhining, and, when black, poſſeſſes a metallic luſtre; it is ſoft, flexible, and heavy.

Before the blowpipe it melts without much difficulty into a dark-grey friable ſlag, containing a ſmall grain of metal. It is not volatilizable, neither does it inflame. This ſubſtance has not been analyſed, and it reſts on the ſole authority of Count Raſumouſky and Baron Born; the former of whom found it in a vein of grey ſulphuretted Antimony at Faucigny, in Savoy; it has alſo been found at Malazka, in Hungary. By Raſumouſky it is conſidered as a phoſphat of Antimony, whereas Born ſuppoſed it to be a combination of the muriats of antimony and lead.

We are as yet but very imperfectly acquainted with the compoſition of moſt of the antimonial ores; it is impoſſible, therefore, to give a very correct method of performing this analyſis.[a] The native antimony, being an alloy of antimony and arſenic, is beſt decompoſed by ſolution in nitro-muriatic acid and precipitation by pure water. For this purpoſe reduce the ore to fine powder, and digeſt it, at a moderate heat, in an acid compoſed of nitric acid, ſp. gr. 1.25 one part, ſtrong muriatic acid, three parts; in this, both the antimony and arſenic will be diſſolved, and the addition of pure water will precipitate the antimony, leaving the arſenic in ſolution. The analyſis of this ore may likewiſe be effected, perhaps with ſuperior accuracy, by digeſtion in ſtrong boiling nitric acid, which will acidify and diſſolve the arſenic, leaving the antimony behind in the ſtate of white oxyd, which may afterwards be diſſolved by nitro-muriatic acid, and precipitated by water.

The grey ſulphurets of antimony, when not cryſtallized, are ſeldom perfectly pure, but contain in combination or intimate mixture, iron, lead, copper, and ſilver; to which muſt be added the earths compoſing the ſtony gangue, from which they cannot be perfectly ſeparated previouſly to analyſis. With theſe compound ores the beſt method of proceeding is to take (*a*) 500 grains, finely pulverized, and digeſt it with 1500 grains of pure nitric acid, ſp. gr. 1.25 and 1000 grains of water for about half an hour, at the temperature of 150° Fahr. then pour in a quantity of pure water equal to the reſt of the fluid, mix the whole well together, and pour off the liquor as ſoon as it becomes clear; it will conſiſt of the nitrats of ſilver, lead, and copper, with probably a little iron, diſſolved in an exceſs of acid. The iron may now be ſeparated in the ſtate of red oxyd by ſimple boiling, and ſubſequent filtration. Then (*b*) drop muriat of ſoda into the ſolution, as long as any precipitate takes place, and allow the whole to ſtand till the ſupernatant fluid becomes perfectly clear; the precipitate is pure muriat of ſilver, which, being ſeparated and waſhed, may be mixed with two or three times its weight of dry pearlaſh, and reduced by fuſion to the metallic ſtate.

(*c*) The ſolution (*b*) muſt now be ſaturated by potaſh or ſoda, and concentrated by evaporation to about one-third of its bulk; cauſtic ammonia, in exceſs, being then added, the lead will be precipitated as white oxyd, and the copper will remain in ſolution. The lead, by fuſion with black flux, will be reduced to the metallic ſtate.

(*d*) The ſolution (*c*) is, laſtly, to be ſlightly acidulated with nitrous acid, from which carbonat of potaſh will throw down the green oxyd of copper, and this may be brought by a low red heat to the ſtate of brown oxyd, 100 parts of which denote 85 of metal.

(*e*) The portion of ore inſoluble in the proceſs (*a*) is to be digeſted, at a temperature ſomewhat inferior to boiling with ſucceſſive portions of nitro-muriatic acid (conſiſting of nitric acid ſp. gr. 1.25 one part, ſtrong muriatic acid three parts) as long as any thing is taken up; the ſolutions being then mixed and concentrated by evaporation, are to be poured into a conſiderable quantity of pure water; an immediate precipitate of white oxyd of antimony will take place, which, being ſeparated and waſhed, and

[a] Bergman's Eſs. Klaproth's Analyt. Eſs. Kirwan's Mineralogy, vol. ii.

mixed with twice its weight of crude tartar, and a little nitre, is eaſily reduced by a full red heat continued for a few minutes to a metallic button.

(*f*) The ſolution (*d*) contains now only a little ſulphuric acid and iron, with ſome earthy matter. The addition of nitrat of barytes, as long as any precipitate falls down, indicates the quantity of ſulphur; after which, an exceſs of cauſtic potaſh, aſſiſted by a boiling heat, will throw down the iron, and retain the alumine and ſilex.

(*g*) The inſoluble reſidue of proceſs (*d*) containing only ſulphur and earth, is decompoſed by ignition, the ſulphur flying off, and the earth remaining.

Thus the quantity of antimony is obtained by proceſs (*e*);
of ſulphur and earth by (*f*) and (*g*);
of iron by (*a*) and (*f*);
of ſilver by (*b*);
of lead by (*c*);
of copper by (*d*).

The grey ſulphuret of antimony is the only ore of this metal which is found in ſufficient quantity for the purpoſes of commerce, and it is fitted for market in the large way by ſimple fuſion.[b] For this purpoſe the ore being dreſſed and ſeparated from the greater part of its ſtony gangue by hand, is placed in the bed of a reverberatory furnace, and covered with charcoal powder; being then brought to a low red heat, the ſulphuret of antimony enters into fuſion, while the earthy parts float on the ſurface, and are taken off with a rake or ladle; the fluid portion is then caſt into the form of loaves or large cakes, and is fit for ſale, forming the *common* or *crude* antimony of the ſhops. The old method of obtaining crude antimony, and which is ſtill practiſed in ſome of the French founderies, was by means of an apparatus conſiſting of a large crucible, the bottom of which was perforated, and inſerted into the wide end of a conical tube, paſſing through the furnace, and terminating in an earthen pot or reſervoir. The crucible was filled with ore broken into ſmall pieces, a cover was luted on, and by the application of a moderate heat, the liquefied antimony dropped through the tube into the reſervoir below, while the ſtony parts were detained in the crucible.

From the crude or ſulphuretted antimony thus prepared, there are ſeveral methods of ſeparating the ſulphur, and procuring the metal in a ſtate of purity; the beſt, and which is the moſt uſed in proceſſes in the great way, is the following.

Reduce the ſulphuret to ſmall pieces, and ſtrew it evenly and thinly on the floor of a reverberatory furnace, in order to drive off the ſulphur by roaſting. The heat at firſt muſt be very gentle, ſcarcely exceeding that required for the fuſion of tin, otherwiſe the antimony will clog or even melt: in a ſhort time a lambent blue flame, proceeding from the combuſtion of the ſulphur, will appear over the ſurface of the ore, which, at the ſame time, will begin to loſe its metallic luſtre, and be converted into a greyiſh oxyd. By aſſiduouſly ſtirring the ore, and cautiouſly increaſing the temperature as its fuſibility decreaſes, it will, in the courſe of ſome hours, ceaſe to emit ſulphureous vapours, and bear a moderate red heat without melting. The roaſting is now finiſhed, and when the ore is removed from the fire, and becomes cool, it will be found converted into an aſh-grey oxyd, weighing from thirty to thirty-ſix per cent. leſs than the original ſulphuret, and ſtill by no means entirely free from ſulphur. In order to obtain the regulus from this grey oxyd, it is to be mixed with half its weight of crude tartar, and expoſed to a full red heat in a covered crucible. The carbonaceous part of the tartar decompoſes the oxyd, and the antimony, reduced to the metallic form, collects itſelf in a maſs at the bottom of the crucible, except a variable proportion, which is held in ſolution by the ſulphuret of potaſh formed by the alkaline baſe of the tartar and the ſulphur of the oxyd. The quantity of metal thus obtained in the large way, equals from 66 to 70 per cent. of the oxyd employed; but a much greater loſs will be obſerved, if the ore has not been properly roaſted. The method followed by T. Kunkel appears, however, on the whole, to be better and more economical than the common practice. He mixes the roaſted oxyd with oil or fat, and a little powdered charcoal, puts the maſs into a crucible to melt, and as ſoon as the regulus begins to ſhow itſelf, injects, by degrees, ſome powdered nitre, in the proportion of an ounce to a pound of oxyd: the matter ſoon appears in thin fuſion, and on being poured out affords a pure regulus, in conſiderably greater proportion than is obtainable by the uſual way of operating.

The expence of nitre and tartar in preparing regulus of antimony in large quantities, for the purpoſe of commerce, is very conſiderable, in conſequence of which a ſeries of experiments were undertaken by Haſſenfratz, Vauquelin,

[b] Journ. des Mines.

and Bouillon la Grange,[c] in order to aſcertain whether the uſe of theſe ſubſtances could be ſuperſeded by cheaper materials. In the proſecution of this enquiry, different portions of the roaſted ore were mixed with charcoal powder, with tallow, and with pitch, and expoſed in covered crucibles to a heat ſufficient for their reduction: the crucibles being then withdrawn were found to contain only a little carbonaceous matter, and a few minute globules of antimony, all the reſt being evaporated. Some grey oxyd was then mixed with 1ſt. two parts of lime and one of clay; 2d. equal parts of ſulphat of barytes, chalk and clay; 3d. with common ſalt; 4th. with ſulphat of ſoda: and the materials being ſtrongly heated, were all found converted into yellow glaſſes, without any appearance of regulus. Theſe being each pulverized, and mixed with charcoal powder, were again heated as before, and produced only vitreous ſcoriæ, with a few minute globules of antimony. Laſtly, ſome of the ſame grey oxyd being fluxed with half its weight of tartar, yielded a perfect button of pure antimony. Hence it appears that potaſh (and probably the fixed alkalies in general,) exert ſome ſpecific action on antimonial oxyd, which renders it much more fixed while converting into regulus, than when mere carbonaceous or even vitreſcent fluxes are made uſe of.

The moſt expeditious, though at the ſame time the moſt expenſive and inaccurate manner of procuring the regulus of antimony, is by *ſcorification*. For this purpoſe eight parts of the grey ſulphuret are reduced to a fine powder, and mingled with ſix parts of tartar and three of nitre. The mixture is projected gradually into a red hot crucible, till it is nearly filled, a ſlight detonation taking place at each ſucceſſive projection: the crucible is now cloſed with its cover, and a briſk heat being applied for nearly half an hour, the contents are either ſuffered to cool in the crucible or are poured into a greaſed and heated iron cone. The upper part of the maſs conſiſts of alkaline ſcoriæ, holding in ſolution a portion of antimonial oxyd, beneath which is a button of pure antimony, weighing between three and four eighths of the original ſulphuret Some adviſe that the nitre and tartar ſhould be detonated together before the crude antimony is added; but this is decidedly an injudicious way of proceeding, the uſe of the nitre being not to alkalize the tartar but to oxygenate the ſulphur; hence it is probable that the yield of regulus would be increaſed by firſt detonating together the nitre and ſulphuret, and not adding the tartar till towards the end of the proceſs.

An exceſs of nitre or tartar, or both, is carefully to be avoided, as it not only enhances the expence but diminiſhes the produce. Lemery[d] found that ſixteen ounces of ſulphuretted antimony, mixed with an equal weight of nitre, and the ſame of tartar, yielded only five ounces and a half of regulus; whereas ſixteen ounces of ſulphuret, twelve ounces of tartar, and ſix ounces of nitre, afforded ſix ounces and one dram of regulus.

There is yet another way of ſeparating the regulus of antimony from the ſulphur with which it is naturally combined, by taking advantage of the ſuperior affinity for ſulphur which other metals poſſeſs over antimony. There are five metallic ſubſtances capable of decompoſing crude antimony with greater or leſs accuracy, by being fuſed together with it; theſe are iron, copper, lead, ſilver, and tin; only the former is at preſent, however, made uſe of, as it is both cheaper and more effectual than any of the reſt. The antimony procured by this method was called by the old chemiſts *Martial regulus*, on account of the uſe of iron in its preparation, a name which may very properly be retained, as it is impoſſible by any other means than ſolution in acids to render this regulus abſolutely free from iron: in ſtrictneſs, therefore, it ought to be conſidered as antimony alloyed with a ſmall and variable proportion of iron. In order to prepare the martial regulus as free from iron as poſſible, the following method, recommended by Lemery and Beaumé,[e] appears upon the whole to be the beſt. Take eight ounces of horſe-ſhoe nails, and heat them in a crucible almoſt to whiteneſs; then add ſixteen ounces of coarſely pounded crude antimony; cover the crucible and keep up the fire; in a few minutes the whole will be melted; at which time add by degrees three ounces of nitre: after a ſlight detonation has taken place, and the whole is brought to a ſtate of perfect fuſion, pour it into an iron cone, previouſly heated and greaſed, and ſtrike the ſides of it gently as the maſs becomes ſolid, to favour the precipitation of the regulus. When cold it will be found to conſiſt of a maſs of antimony, weighing about ten ounces, covered by an alkaline ferruginous ſcoria, from which it may be readily ſeparated by a blow with a hammer. The regulus, however, ſtill contains not only iron but ſulphur; it muſt therefore be remelted, and two ounces of crude antimony, and three ounces of nitre are then to be added;

[c] Ann. de Chim. [d] Sur l'Antimoine. [e] Lemery ſur l'Antimoine. Beaumé Chimie experimentale.

when all detonation has ceaſed, pour it into a cone as before, and ſeparate the regulus from the ſcoriæ. Remelt the regulus, and project upon it three ounces of nitre, then ſeparate this purified regulus from the ſcoriæ, and once more melt it with a ſtrong and rapid heat; project upon it, by degrees, three ounces of nitre, and immediately after pour it into a cone: there will be obtained about eight ounces of a beautiful ſtellated regulus, covered with yellowiſh white ſcoriæ. In this proceſs the materials employed are, eighteen ounces of ſulphuret, eight ounces of nails, and twelve ounces of nitre; four ſeparate fuſions are required, and the product is eight ounces of regulus.

The martial regulus may be procured in a more expeditious way, though not ſo free from iron, by bringing five ounces of horſe-ſhoe nails to a white heat in a crucible, and then adding ſixteen ounces of crude antimony: as ſoon as the whole is in very liquid fuſion, project, at ſeveral times, one ounce of pulverized nitre; when the detonation has entirely ceaſed, put on the cover of the crucible, raiſe the heat for a few minutes, then remove the crucible from the furnace, and allow it to cool very gradually; there will be found beneath the ſcoriæ about ſeven ounces of regulus.

Perfectly pure antimony, whether procured by roaſting or ſcorification, is a metal of a duſky white colour, between that of tin and iron, and exhibits, when recently broken, a remarkable degree of brilliancy: it is entirely deſtitute of ductility, and may, without much difficulty, be reduced by trituration to a fine powder; it is moderately hard, yielding eaſily to a common knife: its fuſibility is rather leſs than that of zinc, as it requires a low red heat to be kept in a liquid ſtate. Its ſpecific gravity, according to Bergman, is 6.86; but by the experiments of Briſſon, amounts only to 6.702. Its fracture is generally broad-foliated, but ſometimes the facets are ſo minute as to give it almoſt a granular appearance: the magnitude of the plates of which it is compoſed, depends for the moſt part on the ſlowneſs with which it is cooled. The primitive cryſtalline form of antimony has not yet been aſcertained; Hauy has found that it is diviſible, at the ſame time parallel to the faces of a regular octahedron, and of a rhomboidal dodecahedron. If a large crucible is filled with melted antimony, and allowed to cool very gradually, and if, as ſoon as a cruſt has formed on the ſurface, the fluid beneath is poured out, by inclining the veſſel and breaking a ſmall hole in the cruſt, the hollow will be found ſtudded with various cryſtalline groups, conſiſting of cubes, of lengthened rectangular parallelepipeds, and of ramifications made up of ſmall octahedrons, implanted into each other, or aggregated into a furrowed trihedral pyramid. The ſtrong tendency of antimony to aſſume a cryſtalline form, is alſo ſhewn by the appearance of a radiated ſtar, or pinnated leaves, like thoſe of fern, with which the ſurface of pure antimony that is not cooled too haſtily is generally covered: this will not take place except the metal is pure or nearly ſo, hence the term *ſtellated* is nearly ſynonimous with purified, regulus. By the alchemiſts this ſtar was conſidered as a myſterious guide to the true method of making gold, which accounts for the vaſt number of alchemical proceſſes that are recorded relative to this metal.

Antimony is but very little diſpoſed to be acted on by air and moiſture, at any degree of the atmoſpheric temperature; after a conſiderable time, however, it is deprived of its luſtre, and covered with an extremely thin coat of firmly adhering black oxyd. By a low red heat, and free contact with the air, it may be entirely converted to a whitiſh grey oxyd, which at a higher temperature is volatilizable, and capable of being more highly oxygenated. When the metal is made to boil by the application of an almoſt white heat, and then expoſed to a current of air, it is rapidly converted into a white vapour, which condenſes as it cools into brilliant cryſtalline needles, of a ſnowy or ſilvery white, which have obtained the name of *argentine flowers* of antimony, or *ſnow of reguline antimony*. In order to prepare this oxyd in perfection, and with economy, the beſt method is [t] to place a wide cylindrical earthenware tube, cloſed up at one end, in a wind furnace, ſo that it ſhall remain in a ſlanting direction, with the mouth projecting a little way through a door, or hole in the ſide of the furnace; and to prevent the inſide of the tube from being too much cooled, an earthen-ware ſtopper muſt be fitted looſely into the open mouth of the tube: when the bottom of this veſſel is red hot, introduce the antimony in ſmall pieces, and cloſe the aperture with the ſtopper. After the metal is melted, it will begin to ſmoke, and the oxyd will be depoſited in ſlender cryſtals upon the ſides of the tube, whence it may be ſcraped off from time to time with a clean iron ſpoon. The firſt cryſtals are often of a yellowiſh colour, perhaps on account of a ſmall portion of ſulphur

[t] Beaumé Chimie experimentale.

yet remaining in the antimony, thoſe that ſucceed, however, are of a brilliant ſilvery white, without the ſmalleſt tinge of any other colour. The cryſtalline oxyd is a pure ſaturated combination of antimony and oxygen, in the proportion of eighty of the former to twenty of the latter, according to the analyſis of Thenard.[a] In many of its properties it reſembles the metallic acids: it is ſparingly ſoluble in water, has a decided taſte, combines with the alkalies into cryſtallizable ſalts, and may be again ſeparated by the action of any of the more powerful mineral acids. When heated by itſelf in a cloſe veſſel, it is converted by the firſt impreſſion of the fire into a yellow oxyd, and afterwards runs down into a yellow glaſs, containing 19 *per cent.* of oxygen; as the heat increaſes it aſſumes a reddiſh brown tint, and approaches nearer and nearer to the metallic ſtate, till it is finally converted into black oxyd, holding no more than 2 *per cent.* of oxygen. The argentine flowers, by haſty fuſion in a crucible, are converted into a vitreous maſs, which when tranſparent is of a yellowiſh orange colour, and has obtained the name of *glaſs of antimony*, and when opaque is of a brown colour, and is called *liver of antimony*: theſe preparations are now, however, entirely obſolete, the common glaſs and liver of antimony being at preſent prepared from the ſulphuretted oxyd.

We now come to conſider the action of acids upon reguline antimony.

The *Sulphuric acid*, when cold, has little or no action upon this metal; but when boiling hot, it is decompoſed with great rapidity, accompanied by a copious extrication of ſulphureous acid gas and violent effervеſcence. If the mixture is diſtilled to dryneſs, a ſmall quantity of ſulphur ſublimes into the neck of the retort, and a maſs of ſulphated oxyd remains at the bottom of the veſſel. When the proceſs is ſtopped ſhort of deſiccation, a white, ſoft, moiſt, and bulky maſs is produced, which, when waſhed with a little water, depoſits a large quantity of white oxyd; the ſupernatant liquor is conſiderably acidulous, and holds in ſolution a little antimonial oxyd, which, however, is ſeparated by the addition of a freſh portion of water. The ſame effect is produced by ſimply heating the fluid, or by the addition of an alkaline lixivium.

The *Sulphureous acid*, whether hot or cold, appears to be incapable of acting on reguline antimony: it will however decompoſe moſt of the ſalts of this metal, eſpecially that produced by the muriatic acid; a white pulverulent precipitate is thrown down on the addition of ſulphureous acid, which appears to be a true inſoluble ſulphate of antimony; it is of an acrid and harſh taſte, and is decompoſable by mere heat, or with extrication of ſulphureous acid by the ſulphuric. In the former caſe, a reddiſh brown ſulphuretted oxyd is produced, which is ſoluble in cauſtic potaſh, and precipitable by muriatic acid, from its ſolution in the form of kermes or hydroſulphuretted oxyd of antimony.

The *Nitric acid*, eſpecially when fuming, is rapidly decompoſed upon antimony, even in the cold: a large diſengagement of nitrous gas takes place, and the metal is converted into a white oxyd. If the antimony is reduced to fine powder, and mingled with only as much acid as is requiſite to form a thin half fluid maſs, the mutual action of the ingredients is ſo rapid as to cauſe actual inflammation. In their ſtrong affinity for oxygen, a remarkable analogy ſubſiſts between antimony and tin; for not only the nitric acid, but even the water with which it is mixed, are decompoſed by the antimony; the azot of the former, and the hydrogen of the latter of theſe fluids combine during their naſcent ſtate, and produce ammonia, which, uniting with part of the undecompoſed acid, occaſions the unexpected appearance of cryſtals of nitrated ammonia, and theſe have ſometimes been miſtaken for nitrat of antimony. The preſence of ammonia in the white oxyd, thus formed, may be further ſhown by mingling it, before it has been waſhed, with quicklime, or cauſtic potaſh, when ammoniacal gas will be immediately diſengaged. After the action of the nitric acid the greater part of the antimonial oxyd will be found undiſſolved at the bottom of the veſſel, but a ſmall portion is held in ſolution by the ſupernatant acid; even this little, however, is precipitated by water, by evaporation, or by expoſure, for a few days, to the open air. The white nitrated oxyd appears to be a ſaturated combination of antimony with oxygen, in the proportion, according to Thenard, of 70 of metal to 30 of oxygen. It is conſidered as one of the moſt refractory and irreducible of the metallic oxyds, when treated in the uſual way with the common fluxes; but when mingled with a little regulus of antimony, and heated in a cloſe veſſel, it becomes, in ſucceſſion, yellow, orange, brown, and then black, in which ſtate it contains only 2 *per cent.* of oxygen, and is eaſily reducible by fuſion with a little tartar.

Muriatic acid, when heated, is capable of diſſolving a ſmall proportion of antimony, of which

[a] An. de Chim. vol. xxxviii. & xli.

a part is again depoſited in the form of a white oxyd, as the liquor cools; the remainder, by gentle evaporation, may be obtained in ſmall needle-ſhaped deliqueſcent cryſtals. If oxyd of antimony is ſubſtituted for the pure metal, a conſiderably greater proportion is taken up by the acid; this muriat, according to Monnet, cryſtallizes in brilliant plates, like boracic acid, and is decompoſable by water.

Muriat of antimony, when deprived of its ſuperfluous water by gentle evaporation, ſo as to be of a thick honey-like conſiſtence, is volatilizable without decompoſition by a moderate heat in cloſe veſſels, and concretes in the form of a ſoft, white, half-ſolid maſs, called *butter of antimony*. It is not, however, by evaporation and diſtillation of the liquid muriat that butter of antimony is uſually prepared, it being found more effectual and economical to have recourſe for this purpoſe to one or other of the following methods. Take one part of reguline antimony, and two or two and a half parts of corroſive muriat of mercury (corroſive ſublimate) mix them accurately by trituration in a Wedgewood ware mortar, and then transfer the maſs into a wide-necked glaſs retort, fitted with a common receiver; a gentle ſand heat being applied, there will firſt riſe a ſmall quantity of a clear liquid, which is to be removed, and afterwards a thick liquor will come over, and concrete in the receiver and neck of the retort into ſolid butter of antimony: the reſidue in the retort conſiſts of mercury and oxyd of antimony, combined with a ſmall proportion of muriatic acid. The cauſe of this change is obviouſly owing to the ſuperior affinity for oxygen poſſeſſed by the antimony, by which both the oxygen and acid are transferred from the mercury, and combined with the former metal, while the ſeparation of the butter of antimony from the oxyd, and from the running mercury depends on its greater volatility. There are two objections however to this proceſs; firſt, that if an exceſs of corroſive ſublimate is made uſe of, a ſmall portion of it is apt to riſe with, and be diſſolved in the butter of antimony; ſecondly, that if there is an exceſs of antimony, the produce of ſalt is very much diminiſhed. A much more advantageous way of preparing this ſalt is to take equal parts of *unwaſhed* ſulphat of antimony and common ſalt, and diſtil the maſs to dryneſs. Butter of antimony is ſolid at the uſual temperature of the atmoſphere, but liquefies with a very gentle heat, and by ſlow cooling, cryſtallizes in parallelepipeds. It is intenſely cauſtic, and deſtroys the organization both of vegetable and animal ſubſtances; by expoſure to the air and light it becomes coloured, and deliquiates into a thick oleaginous fluid; when dropped into pure water it is in a great part decompoſed, a copious white precipitate being thrown down, conſiſting of oxyd of antimony, combined probably with a little muriatic acid; the remainder of the acid holding a ſmall quantity of antimony, ſtill in ſolution, mixes with the water. The white precipitate obtained in this proceſs, after being waſhed and dried, forms the *powder of Algaroth*, (ſo called from Algarotti, an Italian, its inventor) or *Mercurius vitæ*. If ſublimed muriat of antimony is mixed with an equal weight of nitric acid, the liquor becomes immediately very highly coloured, copious orange fumes are diſengaged, a conſiderable heat is excited, and a white oxyd is gradually depoſited. If before the latter effect takes place, the liquor is evaporated to dryneſs, a pure white oxyd remains behind, and this again abſtracted with nitric acid, and then heated to redneſs in a crucible, aſſumes the appearance of a pulverulent maſs, white externally, with a tinge of roſe colour within: it was known by the old chemiſts, and is deſcribed, in the ancient pharmacopoeias, under the name of *Bezoar mineral*, and is in fact nothing elſe than a very perfect oxyd of antimony.

The *oxygenated muriatic acid*, when in the ſtate of gas, exerts a very ſtriking action on reguline antimony: if this metal, previouſly reduced to fine powder, is thrown by ſmall quantities at a time, into a vial filled with the acid gas, each parcel will take fire, and burn with a bright flame, throwing out at the ſame time a number of ſparks, and forming a beautiful ſhower of fire; the antimony is found at the bottom of the veſſel, converted into the white muriatic oxyd. The liquid acid oxygenates the metal, and diſſolves a ſmall part of it: but it has not yet been aſcertained whether this compound is a muriat or oxymuriat of antimony, probably, however, it is only a muriat.

The beſt ſolvent of reguline antimony is *nitro-muriatic acid*, compoſed of three parts of ſtrong muriatic acid, and one part nitric acid. If the acid is made ſomewhat warm, and the metal added by ſmall pieces at a time, taking care not to add a ſecond till the preceding portion is completely diſſolved, it may thus be charged with a large proportion of antimony, a ſmall part of which only is depoſited by cooling. This, however, like all the foregoing antimonial ſalts, is decompoſable by the addition of diſtilled

water: a piece of iron or zinc throws down the metal in the ſtate of black oxyd, which, when dried at a low temperature, has been obſerved by Thenard, to exhibit the properties of a pyrophorus, inflaming ſpontaneouſly by expoſure to the air.

The *Fluoric* and *Boracic acids* have no action on reguline antimony; but when digeſted on the grey oxyd of this metal they combine with it, and form cryſtallizable ſalts, the properties of which have not yet been examined.

The *arſenic acid*, when digeſted upon reguline antimony, produces two compound ſubſtances; one remains inſoluble at the bottom of the fluid, and conſiſts of the oxyds of arſenic and antimony, being an arſenite of antimony; the other is diſſolved in the ſupernatant liquor, and is either a true arſeniat of antimony, or, perhaps, differs from the inſoluble reſidue only, in containing a ſmaller proportion of antimony. The former of theſe ſalts is ſoluble in muriatic acid, from which it is precipitable by water. [h] If dry arſénic acid and regulus of antimony are diſtilled together, as ſoon as the maſs becomes fluid, an inflammation takes place, regulus of arſenic ſublimes into the neck of the retort, and what remains behind is a mixture of the oxyds of arſenic and antimony. Arſénic acid has no effect on the ſublimed muriat of antimony, but the neutral arſeniats decompoſe it without difficulty, throwing down an arſeniat of antimony.

The effect of the vegetable acids upon metallic antimony is ſcarcely perceptible: thoſe however of its oxyds which are not ſaturated with oxygen are ſoluble without much difficulty. *Tartareous acid*, by long digeſtion, may be made to take up about one-third or one-fourth of its own weight of antimonial oxyd: the ſolution, when evaporated and cooled down to the proper temperature, depoſits a few cryſtalline grains of *tartrite of antimony*; by far the greater portion, however, is of a gelatinous conſiſtence, and has not been much examined. Tartrite of potaſh will alſo take up nearly as much antimonial oxyd as tartareous acid does; the liquor becomes ſlightly alkaline, and depoſits, by evaporation, a number of cryſtalline grains. But the combination of cream of tartar, or acidulous tartrite of potaſh, with antimony, commonly known by the name of *emetic tartar*, is that which, from its importance in medicine, has been the moſt accurately examined.

A ſolution of tartareous acidulum takes up at a boiling temperature a conſiderable proportion of oxyd of antimony, and by evaporation and cooling depoſits elongated octahedral cryſtals of emetic tartar. As, however, the materials of this ſalt are hardly ever perfectly pure, and as the method of preparing it is by no means uniform; the efficacy of this important medicine is liable to conſiderable variation, as well as the analyſes that have been publiſhed of its component parts. Common cream of tartar is always contaminated with a ſmall quantity of tartrite of lime, and the glaſs of antimony which is the antimonial oxyd generally made uſe of, contains, beſides, a variable proportion of ſulphur, as well as ſome ſilex, from the earthen crucibles in which it is made, and which are, in ſome degree, corroded by it. In order, therefore, to prepare a pure and uniform emetic tartar in the moſt economical manner, the following directions muſt be carefully attended to.

Take 12 ounces of glaſs of antimony, and reduce it to a very fine powder, to which add a boiling hot ſolution of 16 ounces of cream of tartar in 14 quarts of rain water; put the whole in a proper veſſel on a digeſting ſand bath, and keep ſtirring it with a ſtick for the ſpace of half an hour; the liquor will ſoon be covered with a browniſh froth, and ſome ſulphuretted hydrogen gas will be given out; when the diſengagement of this gas begins to ceaſe, make the ſolution boil gently for about ten minutes, after which, remove the veſſel from the fire, and when the liquor is become clear, transfer it into a clean evaporating diſh, and, by a very gentle heat, reduce it almoſt to dryneſs, in order to precipitate the ſilex, which would otherwiſe convert the whole to a gelatinous maſs, and prevent, in a conſiderable degree, the after cryſtallization: when the ſalt is nearly dry, add hot water as long as any thing continues to be diſſolved; then ſtrain the liquor, which will be of a bright wine colour, and evaporate it to a pellicle: by ſtanding for a night, a number of octahedral and tetrahedral cryſtals will be depoſited, which are pure antimoniated tartar, and by further evaporation and cooling, a freſh quantity may be obtained, being altogether ſomewhat more than the tartar made uſe of. The taſte of this triple ſalt is ſlightly harſh and metallic: it reddens vegetable blues, as do almoſt all the other metallic ſalts. When expoſed to the air it loſes its tranſparency, and becomes covered over with a white powder. It requires for its ſolution about forty times its weight of boiling water and nearly twice as much as the common temperature. Sulphuric acid precipi-

[h] Scheele's Eſſ. p. 183.

tates from it a ſulphated oxyd of antimony, leaving the tartar nearly pure: the alkalies, both the cauſtic and carbonated, effect only a partial decompoſition, a looſe white oxyd being precipitated by the firſt, and by the ſecond, a carbonated oxyd, which, after a time, cryſtallizes in the form of divergent rays. If either tartareous acid, or tartrite of potaſh, is added to the ſolution of antimoniated tartar, previouſly to pouring in the alkali, there will be no precipitate, for the tartrite of potaſh, produced by the addition of the alkali, immediately rediſſolves the antimonial oxyd. A ſimple ſolution of emetic tartar is for the ſame reaſon incapable of being totally decompoſed by any quantity of alkali, and hence probably have ariſen the great ſeeming differences in the conſtituent parts of this ſalt, according as it has been analyſed by means of a pure alkali, a carbonated alkali, or other reagents. According to Thenard[1] the pure cryſtals of emetic tartar, from whatever antimonial oxyd they have been prepared, and whatever has been the proportion of ingredients employed, contain, in a given weight, preciſely the ſame quantity of antimony, of tartareous acid, of potaſh and water, and even the degree of oxydation of the metal is alſo invariable. His method of analyſing this ſalt is firſt to aſcertain its water of cryſtallization, by drying in a heat juſt not ſufficient to decompoſe it; ſecondly, to diſſolve the emetic tartar, and precipitate the antimony by ſulphuretted hydrogen; thirdly, to aſcertain the tartareous acid by the addition of acetite of lead, as long as any precipitate is produced; and laſtly, to determine the quantity of potaſh, by igniting the reſidue, and extracting the alkali by diluted nitric acid. By a very careful analyſis, conducted according to the above method, M. Thenard found 100 parts of emetic tartar to contain 38 oxyd of antimony,

34 tartareous acid,
16 potaſh,
8 water,

96
4 loſs

100

but the tartareous acidulum, which ſupplies both the acid and alkali to the emetic tartar, contains 57 tartareous acid, 33 potaſh, and about 10 water and loſs; or 70 tartrite of potaſh, and 20 tartareous acid, in exceſs; hence it follows that the mother water remaining from the preparation of emetic tartar, contains an antimoniated tartrite of potaſh, which ſalt is neceſſarily mixed with the former, when prepared by evaporation to dryneſs, inſtead of cryſtallization, and muſt, no doubt, in ſome degree modify its effect upon the conſtitution, producing variations which are unjuſtly attributed to the pure emetic tartar.

Oxalic acid, by digeſtion with oxyd of antimony, takes up a conſiderable proportion, and the liquor depoſits on evaporation, oxalat of antimony in ſmall cryſtalline grains. This ſalt is ſparingly ſoluble either in water or wine. The latter preparation has an emetic quality, and has been uſed in medicine, inſtead of the common antimonial wine. Acetite of antimony is prepared in the ſame way with the foregoing ſalt: it forms minute cryſtals, and was one of the firſt antimonial ſalts that was uſed in medicine on account of its emetic quality: it was firſt adminiſtered by Angelo Sala, but is now wholly ſuperſeded by the antimoniated tartar.

Of the neutral ſalts there are only three, the action of which on antimony has been much noticed, namely, the ſulphat, oxymuriat, and nitrat of potaſh.

Sulphat of potaſh (and probably ſulphat of ſoda) is decompoſable by antimony in the dry way. This fact was firſt noticed by Monnet; he fuſed in a crucible two parts of ſulphated potaſh, mixed with one of pulverized antimony, and obtained a yellow, cauſtic, ſemivitrified maſs of antimoniated ſulphuret of potaſh, which, when waſhed with hot water, was partially ſoluble in that fluid, and, as it cooled, was precipitated in the form of kermes, or hydro-ſulphuretted oxyd of antimony. The metal therefore was oxydated at the expence of the ſulphuric acid, and the ſulphuret of potaſh reſulting from this decompoſition, united with the metallic oxyd, rendering it ſoluble in water.

Oxymuriat of potaſh acts with great energy on antimony, as indeed it does on all the eaſily combuſtible metals. If equal parts of this ſalt, and of antimony previouſly reduced to a fine powder, are mixed together, and ſtruck briſkly on an anvil, a remarkably loud detonation takes place; if the mixture, inſtead of being ſtruck, is poured into ſulphuric acid, or rather if ſulphuric acid is poured *upon* the powder, a hiſſing noiſe is produced, red ſparks are emitted, and the metal is converted into an oxyd.

Nitre and antimony in equal parts, or two parts of the former to one of the latter, being

[1] Ann. de Chim.

thrown into a red hot crucible, detonate with a vivid flame; the acid of the nitre is decompoſed, and the metal is reduced to a perfect oxyd. The white maſs remaining in the crucible is decompoſed by digeſtion in warm water, into a ſoluble and inſoluble part. The latter of theſe was formerly conſidered as a pure oxyd of antimony, but the experiments of Thenard ſhew that it contains about one fifth of potaſh, intimately united with the oxyd, which appears to act the part of an acid. It was formerly known by the name of *reguline diaphoretic antimony*, but may be more properly denominated *antimonite of potaſh*, rendered inſoluble by exceſs of oxyd. The ſoluble part differs from the other merely in the proportion of its ingredients; it is readily cryſtallizable, and may be decompoſed, with precipitation of its oxyd, by any of the mineral acids.

The different combinations of antimony with ſulphur have been treated of much at large both by the ancient and modern chemiſts; we ſhall therefore endeavour to give a full, though compendious ſummary of the eſtabliſhed facts and modern opinions relative to this intereſting inveſtigation.

If equal parts of flowers of ſulphur and reguline antimony are pulverized together, and expoſed in an earthen crucible to a low red heat, they combine with each other, and melt into a denſe uniform maſs of a ſtriated fracture and metallic luſtre, and, in ſhort, poſſeſſed of all the phyſical and chemical properties of the native grey ſulphuret already deſcribed; hence, for cheapneſs' ſake, all the preparations from the antimonial ſulphuret are made with the native ore, or crude antimony, or antimony of the ſhops.

When the ſulphuret of antimony is expoſed to a red heat, with acceſs of air, moſt of the ſulphur, together with a ſmall portion of the metal, is volatilized. If this operation is performed in a melting pot, ſurmounted with a ſeries of aludels, the vapour condenſes on the inner ſurface into a light pulverulent ſubſtance, called *flowers of Antimony*. Theſe, at the beginning of the proceſs, are of a greyiſh yellow colour, and conſiſt of ſulphur, with antimony either in the metallic ſtate, or at leaſt, very little oxydated; the next portions are orange-coloured, and thoſe which riſe towards the end of the operation are almoſt yellow, and conſiſt of little elſe than pure ſulphur. What remains behind is a grey aſh-coloured oxyd, ſtill holding a little ſulphur; among the old chemiſts it was known by the name of grey calx of antimony; by the moderns it is called the *grey ſulphuretted oxyd of antimony*. It is moſt commonly prepared by ſlow roaſting of the crude antimony in a flat diſh, or reverberatory furnace.

The grey ſulphuretted oxyd, when urged by a ſufficient degree of heat, forms a tranſparent glaſs, poſſeſſing, according to circumſtances, every ſhade of colour, from light yellow to the deepeſt hyacinthine red: this is the *glaſs of antimony*, or, according to the modern nomenclature, the *vitreous ſulphuretted oxyd* of antimony. In order to prepare it, any quantity of the grey oxyd is put into a crucible, and kept at a low white heat till it enters into perfect fuſion: ſoon after this has taken place, the end of a clean tobacco pipe ſhould be dipped in, and if the matter that adheres to the pipe is tranſparent, and may be drawn into threads like common glaſs, it has been heated ſufficiently: the crucible is then to be removed from the fire, and its contents are to be poured on a flat ſtone, or plate of copper. When the glaſs has become ſolid, it ſhould be removed into a covered veſſel, as it cracks and flies while cooling.

It ſometimes happens in making the glaſs of antimony, that the grey oxyd begins to melt as ſoon as it is red hot, and continues limpid like water, without acquiring the tenacity of glaſs; at other times on the contrary, even the long continuance of a white heat will only bring it to a paſty conſiſtence. In the former caſe, the glaſs is of an unuſually deep colour; in the latter, it is almoſt yellow. This inequality ariſes from a difference in the oxyd: if it has been too little roaſted, it flows with the firſt impreſſion of the heat, but when more completely oxydated and deſulphuretted, it proves very refractory: in this caſe, however, it may be remedied by throwing in a little crude antimony in powder, which will immediately determine its fuſion and vitrification, while a portion of the antimony deprived of its ſulphur, will fall to the bottom, in form of metallic globules.

If the previous deſulphuration has been very ſlight, the oxydation will alſo have proceeded but a little way; and the glaſs produced, though poſſeſſed of a vitreous fracture, is perfectly opaque, and of a dark liver colour; hence it has obtained the name of *Liver of Antimony*: the ſame name, however, has been given to a preparation of crude antimony and nitre, which will be mentioned preſently.

The action of acids upon the ſulphuret of antimony is, upon the whole, ſo ſimilar to their action on the regulus, that it will only be neceſſary to point out the circumſtances in which

they differ. In general, the metallic part of the ſulphuret is more eaſily diſſolved, and retained by acids, than the mere regulus is, and the ſulphur of the compound is either not at all, or, at leaſt, very ſlightly acted on. The ſulphuric and nitric acids are decompoſed with conſiderable energy on pulverized ſulphuret of antimony; ſulphureous acid in one caſe, and nitrous gas in the other, being copiouſly diſengaged; the metal is oxydated, and remains intimately mixed, though no longer combined with the ſulphur, very little of it being actually diſſolved by theſe acids. The muriatic acid, even when cold, will decompoſe a large quantity of ſulphuret, during which proceſs there is a conſiderable extrication of ſulphuretted hydrogen. If the mixture is heated, the whole of the metal enters into ſolution, leaving the ſulphur at the bottom unaltered; a ſmall portion, however, both of the ſulphur and metallic oxyd is diſſolved in the hydrogen, and eſcapes in a gaſſeous form; for Bergman obſerved, by performing this experiment, in a veſſel with a long narrow neck, that the ſulphuretted hydrogen in its paſſage through, depoſited ſome kermes or hydroſulphuretted oxyd of antimony. The beſt menſtruum for crude antimony is an aqua-regia, with a conſiderable exceſs of muriatic acid; by this the metallic oxyd is entirely diſſolved, and the ſulphur (about 26 per cent.) is left at the bottom of the veſſel, in the form of a white powder, except a very ſmall portion which is acidified.

The fixed alkalies are capable of combining in the dry way with ſulphuretted antimony, forming ſeveral important preparations. If 15 ounces of pulverized crude antimony, 12 ounces of decrepitated muriat of ſoda, and 3 ounces of tartar are mixed together, and fuſed in an earthen crucible, there will be found, on breaking the veſſel when cold, that it contains two ſubſtances; the upper is of a light colour, and conſiſts of the muriated ſoda with a little ſulphur; the inferior maſs is very heavy, opaque, of a black colour, and, on being broken, exhibits a ſhining vitreous fracture: it has obtained the name of *medicinal regulus*, and is a ſimple alkalized ſulphuret of antimony, the metal being nearly ſaturated with ſulphur, and probably uncombined with oxygen. A ſimilar preparation to this is the *ruby of antimony*, or *magneſia opalina*, differing, however, in containing leſs ſulphur, and in the metal being ſlightly oxydated. It is prepared by mixing equal parts of muriated ſoda, nitre, and crude antimony, and fuſing the maſs in a crucible; there is a large quantity of ſcoriæ in this, as in the former proceſs, and underneath them is a compact vitreous ſubſtance, tranſparent in thin ſhivers, of a deep ſomewhat ſmoak-red colour, and brilliant metallic luſtre. Neither of theſe preparations is deliqueſcent or ſoluble in water, on account of the ſmall quantity of alkali that they contain. By increaſing, however, the doſe of alkali the maſs becomes ſoluble: thus, if to one part of ſulphuretted antimony we add two parts of pure dry pearlaſh, we obtain by fuſion, a reddiſh-brown maſs of alkaline ſulphuret of antimony, and a little of the metal in its pure reguline ſtate, is found at the bottom of the crucible. This alkaline ſulphuret, being previouſly reduced to a coarſe powder, is almoſt entirely ſoluble in boiling water, and, while quite hot, may be paſſed through a filter to ſeparate the impurities; but as the liquor cools, a copious precipitate takes place of a bulky flocculent ſubſtance, whoſe colour is a deep brick red, approaching to that of the kermes inſect, whence it has been called *Kermes mineral*: after the depoſition of the kermes has ceaſed, the liquor being ſeparated by the filter, is of a wine-yellow colour, and, upon the addition of any acid, a ſecond precipitation is brought about of an orange-yellow powder, which is called the *golden ſulphur* of antimony.

Kermes may alſo be prepared in the humid way, as was firſt ſhewn by Lemery in the year 1707. Since that period, a multitude of proceſſes have been publiſhed by the French chemiſts for the preparation of this ſubſtance, none of which, however, appear to be improvements of Lemery's original method, which is as follows[k]. Put into a clean iron pan five or ſix parts of a lixivium of cauſtic potaſh with fifteen or twenty of water, ſet it over the fire to heat, and as ſoon as it begins to boil, throw in ſome well levigated ſulphuret of antimony, equal in weight to one-ſixteenth of the alkali; ſtir the mixture well, and when it has boiled for a minute or two, throw the whole on a filter, ſo that the clear liquor may paſs through while hot; a large quantity of kermes will be depoſited as the ſolution cools, which, after being ſeparated from the alkaline liquor, is to be well waſhed, firſt in cold water, and then in hot, till the water comes off quite inſipid: the powder being then dried in the ſhade by a very gentle heat, and levigated, and paſſed through a fine ſieve, is to be kept in a glaſs phial for uſe. The alkaline liquor, when it has ceaſed to depo-

[k] Beaumé Chim. Exper. vol. II. p. 332.

fit kermes, may be made to yield the golden ſulphur by ſaturating it with diluted ſulphuric acid. In this proceſs by the humid way, as in the other by the dry way, a partition of the ſulphur takes place between the alkali and the metal, by which a portion of this laſt is left undiſſolved in the form of a grey powder, and this, by ſimple fuſion in a crucible, is reduced to a maſs of regulus.

According to the French chemiſts, both kermes and golden ſulphur are *hydroſulphuretted oxyds of ſulphuret of antimony;* and Thenard, in his experiments on the antimonial oxyds (already quoted) has given the following as the reſult of his analyſis of theſe two ſubſtances. Kermes mineral contains

72.760 brown oxyd of antimony,
20.298 ſulphuretted hydrogen,
4.156 ſulphur,

97.214
2.786 loſs

100.000

golden ſulphur contains

68.3 orange oxyd of antimony,
17.877 ſulphuretted hydrogen,
12. ſulphur,

98.177
1.823 loſs

100.000

The theory concerning their formation is, that the alkaline antimonial ſulphuret coming into contact with water decompoſes it; that the oxygen of the water combines with the ſulphuretted metal, while its hydrogen diſſolves ſome of the ſulphur with which it is in contact, and unites to the ſulphuretted metallic oxyd in different proportions, according to the different degrees of oxydation of theſe oxyds; that when the antimony is the leaſt oxydated, it unites with the greateſt quantity of ſulphuretted hydrogen, and becomes inſoluble in the alkali, forming kermes; and, on the other hand, when more oxydated, it unites with leſs ſulphuretted hydrogen, and remains diſſolved in the alkali, till precipitated from it by the action of an acid, forming the golden ſulphur. Kermes may alſo be made by paſſing ſulphuretted hydrogen through a ſolution of the muriat of antimony, and this, among others, is adduced as a proof of the kermes containing the metal in an oxydated ſtate.

The nature of the preparations that reſult from the mutual action of nitre and ſulphuretted antimony depends principally on the proportion which the nitre bears to the other ingredient. The nitric acid is conſumed in acidifying the ſulphur, and oxydating the antimony, and the alkaline baſe of the nitre unites with the ſulphur, (if any remains) with the ſulphuric acid, forming ſulphat of potaſh, and with the metallic oxyd. When the nitre conſiderably exceeds the antimonial ſulphuret, as in the preparation of diaphoretic antimony, the ſulphur is entirely oxygenated, and partly eſcapes in the form of ſulphureous acid gas, while the remainder, with part of the alkali, forms ſulphat and ſulphite of potaſh; the metal alſo is compleatly oxygenated at the expence of the nitre; and the oxyd thence reſulting combines with the potaſh in two proportions; that portion which is united to a large quantity of alkali is rendered ſoluble, and the other remains inſoluble. Hence, when the reſult of the above proceſs is lixiviated with hot water, we find diſſolved in the liquor, and may obtain in a cryſtalline form ſulphat and ſulphite of potaſh, ſome undecompoſed nitre and antimonial potaſh: the undiſſolved reſidue, or diaphoretic antimony conſiſts of the perfect oxyd of this metal, combined with about a fifth of potaſh. When the nitre and crude antimony are only in equal proportions, part of the ſulphur is acidified, and the metal is brought to a low ſtate of oxydation: by the action of warm water, the maſs is divided into a ſoluble and inſoluble portion; the former conſiſts of kermes, of golden ſulphur and ſulphat of potaſh; the latter is of a reddiſh brown colour, hence called *crocus metallorum*, and is probably nothing elſe than a ſulphuretted oxyd of antimony.

Phoſphorus unites with antimony, according to Pelletier[1] by projecting on the melted regulus ſmall pieces of phoſphorus, and immediately afterwards removing it from the fire, or by fuſing together equal parts of glaſs of phoſphorus and the metal, either with or without charcoal; the reſult is a white metallic maſs of *phoſphuret of antimony*, very brittle, of a lamellar ſtructure, and breaking into nearly cubical fragments. When expoſed on charcoal to the action of the blow-pipe, it emits, at the moment of fuſion, a faint green flame, and then volatilizes like pure antimony in the form of white flowers.

[1] Memoires de Chimie, vol. II. p. 54.

Only one or two of the alloys of antimony are used in the arts, and even these have by no means been subjected to accurate chemical examination, of the rest we are almost entirely ignorant.

ANTIMONY and GOLD. See GOLD.

ANTIMONY and PLATINA. See PLATINA.

ANTIMONY and SILVER. See SILVER.

ANTIMONY and COPPER.

These two metals fused together in nearly equal proportions, form a hard brittle alloy of a violet colour and striated texture, which is not very soon affected by exposure to the air. Its specific gravity, according to Gellert,[m] is greater than the mean of its ingredients. It is not made any use of.

ANTIMONY and IRON.

The general properties of antimony, with a very small proportion of iron, or *martial regulus*, we have already mentioned. Gellert[n] fused together 115 grains of iron with 173 gr. of antimony, and obtained a brittle ash-coloured alloy, full of specks like rust of iron, of less specific gravity than the mean of its ingredients, and not attractable by a powerful magnet.

ANTIMONY and MERCURY. See MERCURY.

ANTIMONY and TIN.

These two metals being mixed in equal proportions, form a moderately hard, brittle, and very brilliant alloy, capable of receiving an exquisite polish, and not easily tarnished by exposure to the air; it has been occasionally manufactured into speculums for telescopes. Its sp. gravity according to Gellert [o] is less than the mean of its constituent parts. See SPECULUM METAL.

ANTIMONY and LEAD.

Gmelin [p] found that equal parts of these two metals produced a porous brittle alloy; one part antimony and two lead gave a homogeneous metal much harder than lead, but ductile under the hammer: one part antimony and eight lead formed an alloy more fusible, harder, and whiter than lead without impairing its ductility. According to Gellert [q], 386 gr. of lead and 333 of antimony afforded a brittle alloy, with a granular somewhat shining fracture, whose specific gravity was greater than the mean of its constituent parts. Antimony, lead, and a little copper, form TYPE-METAL.

ANTIPHLOGISTIC *theory*. See PHLOGISTON.

ANTHRACITE. See KOHLENBLENDE.

APATIT [r]. *Native phosphat of Lime. Chaux phosphaté* of Hauy. *Phosphorite* of Kirwan.

Apatit, when pure, is soluble without effervescence in nitric acid. Its crystals are divisible parallel to the sides and extremities of a regular hexahedral prism. By distillation with charcoal, in close vessels, it gives out a phosphoric light and odour, and a little phosphorus. It is divided by the German mineralogists into the three following species.

I. Conchoidal Apatit.; *Muschlicher Apatit; Spargelstein; Chrysolithe* of Delisle and Born; *Pierre d'Asperge* of Brochant.

The colour of this mineral is yellowish or bluish green, or orange, or browniish-red. It crystallizes in regular hexahedral prisms, terminated by hexahedral pyramids with triangular faces (pyramidé of Hauy); or in hexahedral prisms, terminated by wedge-shaped summits (cuneiforme of Hauy), or finally, the edges of the prism are deepily bevilled, so as to make it dodecahedral, in consequence of which the terminal pyramids have pentagonal faces (didodecaedre of Hauy). The crystals are very small, rarely equalling eight lines in heighth, and are slightly striated longitudinally. Externally it is shining or much shining, internally it is much shining, with somewhat of a greasy lustre. The cross fracture is flat-conchoidal, passing into uneven and splintery; the longitudinal fracture is imperfectly foliated. When broken, it flies into irregular sharp-edged fragments, which have often a tendency to the rhomboidal figure. It is generally transparent, but sometimes only translucid, gives a greyish-white streak, may be scratched readily by a knife; sp. grav. of the Spanish apatit, 3.09, of the Norwegian, 3.15.

The Spanish apatit was analysed by Vauquelin, [s] and found to contain

53. 8	lime,
46.19	phosphoric acid,
92.27	

This mineral is soluble without effervescence, in warm nitric or muriatic acid. When exposed to the blow-pipe it does not decrepitate nor lose its transparency: it becomes however

[m] Chimie. metallurgique vol. i. p. 265. [n] Ibid. p. 272. [o] Ibid. p. 267. [p] Ann. de Chim. vol. viii. p. 319.
[q] Chim. metallurg. vol. i. p. 269. [r] Emmerling, Lehrbuch der Mineralogie v. ii. p. 757. Hauy, Traité de Mineralog. v. ii. p. 234. Nouv. Dict. d'Hist nat. art. Apatite. [s] Journ. des Mines, v. vii. p. 19.

colourleſs, and then reſembles rock-cryſtal. With borax it forms a milk-white imperfectly fuſed maſs; when pulverized and thrown on hot coals, it does not exhibit any phoſphoreſcence.

The Spaniſh apatit was firſt diſcovered by M. Launoy, at Mount Caprera, near Cape de Gata, in the Province of Murcia; it is found in a yellowiſh-white carious rock, accompanied with magnetic and micaceous iron ore, pyrites, and ſmall plates of calcareous ſpar: the cryſtals are of the yellowiſh-green, and orange-coloured varieties; the latter of which, at firſt ſight, are liable to be confounded with that variety of cryſtallized quartz called the Hyacinth of Compoſtella.

The Norwegian apatit includes the bluiſh-green and browniſh-red varieties, and is found in the diſtrict of Arendahl, mixed with ferruginous hornblende, calcareous ſpar, and amorphous apatit.

II. Foliated Apatit. *Blättriger Apatit; Geneiner Apatit; Apatite commune* Brochant.

The colour of this mineral is generally mountain green, ſometimes pale yellowiſh-green, paſſing into olive-green, light wine-yellow and clove brown; it is alſo found of a middle tint, between fleſh and roſe-red, or hyacinth-red, greeniſh yellowiſh and pearl grey, and violet-blue; ſometimes it is ſnow-white, and when tranſparent, perfectly colourleſs. The ſame cryſtal will often exhibit various ſhades and colours, and a few ſpecimens are found irideſcent. It is moſt commonly met with cryſtallized in regular hexahedral priſms (primitive of Hauy); in dodecahedral priſms, formed by bevelling the edges of the hexahedral priſm (peridodecaedre of Hauy); in hexahedral priſms terminated by deeply truncated hexahedral pyramids (annulaire of Hauy); in the ſame with the ſolid angles at the baſe of the pyramids truncated (unibinaire of Hauy); in dodecahedral priſms terminated by deeply truncated hexahedral pyramids (emarginé of Hauy). The cryſtals are generally very ſmall, and ſtriated longitudinally: they are ſhining or much ſhining, with a vitreous luſtre. The croſs fracture is ſtrait foliated, ſometimes almoſt ſpecular; the longitudinal fracture is uneven with fine grains, or imperfectly conchoidal. It is commonly ſemi-tranſparent, paſſing on the one ſide into tranſparent, and on the other to tranſlucid on the edges. Its hardneſs is ſomewhat ſuperior to that of fluor-ſpar. Sp. gr. 3.19 to 3.21. Its conſtitutent parts, according to Klaproth, are

55 lime
45 phoſphoric acid, with a little manganeſe

100

When reduced to coarſe powder, and ſtrewed on hot coals, it ſhines with a graſs-green phoſphoric light.

It is found at Ehrenfriederſdorf, in Saxony; at Schlackenwalde and Kuttenberg, in Bohemia; and at Schwartz-Leogang, in Saltzburg. It accompanies the tin ores, and is mixed with fluor-ſpar, ſteatite, quartz, tin-ſtone, pyrites, manganeſe and wolfram.

III. Earthy Apatit. *Erdiger Apatit; Apatite terreuſe* Brochant.

The colour of this mineral is reddiſh, greyiſh or yellowiſh white, ſtained ſuperficially with browniſh or Iſabella yellow. It is found in maſs, exhibiting ſometimes an obſcurely lamellar ſtructure. It poſſeſſes little or no luſtre, and has an earthy fracture, paſſing into the fine-grained uneven. It is opaque; half-hard, often friable. Sp. gr. 2.82 to 2.86.

It was analyſed by Bertrand, Pelletier, and Donadei, and found to contain

59. lime,
2. ſilex,
1. oxyd of iron,
34. phoſphoric acid,
2.5 fluoric acid,
1. carbonic acid,
0.5 muriatic acid.

100.0

When expoſed to the blowpipe it becomes phoſphoreſcent, and melts, though with difficulty, into an opaque white glaſs. If ſcratched with a knife, it exhibits a faintly luminous trace: when coarſely pulverized, and ſtrewed on hot coals, it undergoes no decrepitation, but heats quietly, and is ſoon penetrated with a phoſphoreſcent light, which hovers for ſome time over its ſurface, in the form of a bright green luminous vapour. *

It is found in ſtrata, penetrated by quartz, at Logroſan, in the province of Eſtremadura, at the foot of a mountainous ridge called Guadelupe, where it is uſed as a common ſtone for building, and where its luminous quality has been long known and admired.

The phoſphoric earth of Kobolo-Bojana, in the province of Marmaroſh, in Hungary, is extremely ſimilar to the earthy apatit. When

* Prouſt in Journ. de Phyſ. vol. xxxii. p. 243.

ſpread on hot coals, it gives a pale yellowiſh light, and, according to Pelletier's analyſis,[d] contains

1.	water,
31.	ſilex,
21.	lime,
15.5	alumine,
1.	oxyd of iron,
1.	muriatic acid,
1.	phoſphoric acid,
28.5	fluoric acid,
100.0	

In ſome ſpecimens the proportion of fluoric acid is conſiderably leſs, and that of phoſphoric acid is greater.

APPARATUS *Chemical.* For this important article ſee the Appendix to vol. 2.

APPLES, *Acid and Juice of.* See MALIC *Acid.*

AQUA. A term applied to many liquid preparations in chemiſtry, and eſpecially in pharmacy. In the former the term is now little uſed; in the latter it is very generally adopted, to imply ſolutions of various ſubſtances in water in certain proportions, or diſtilled waters uſed in medicine. The following are occaſionally uſed in chemiſtry.

Aqua Ammoniæ Acetatæ. A. Acetitis Ammoniæ. A ſolution of ACETITED *Ammonia.*

Aqua Ammoniæ Puræ, or *Cauſticæ.* A ſolution of AMMONIA in water.

Aqua Calcis, or LIME *Water.*

Aqua Potaſſæ. A. Kali Puri. A ſolution of cauſtic POTASH.

Aqua P. Kali Preparati. A ſolution of CARBONATED *Potaſh.*

AQUA-FORTIS. *Eau Forte*, Fr. *Schiedewaſſer*, G. The term which aſſayers and workers of metals give to NITROUS acid. They diſtinguiſh two kinds of aqua-fortis, the *double*, which is common nitrous acid, and the *ſingle*, which is the former diluted with an equal weight of water. But in many of the finer operations, a much more accurate diſtinction of the ſtrength of the acid is required.

AQUA REGIA. The NITRO-MURIATIC *Acid*, called *Regia* on account of being the ſolvent for gold, the *king* of metals.

AQUA-VITÆ. *Eau de Vie.* A name commonly applied to native diſtilled ſpirits in the different countries in which they are prepared. Hence it means *Brandy, Whiſky, Malt Spirits*, &c. reſpectively.

AQUA-MARINE. See BERYL.

ARABIC GUM. See MUCILAGE.

ARBOR DIANÆ. See SILVER.

ARCHIL. See LITMUS.

ARDENT SPIRIT. See ALCOHOL.

ARDOISE. See THONSCHIEFER.

AREOMETER. See GRAVITY SPECIFIC.

ARGENTINE. See SCHIEFER-SPATH.

ARGENTINE, *Flowers of Antimony.* See ANTIMONY.

ARGENTUM MOSAICUM. This is a metallic alloy in the form of ſilvery flakes, uſed as a pigment for giving a white metallic luſtre to plaſter caſts, paper, porcelain, &c.

It is prepared in the following manner. Take an ounce and a half of grain tin, and the ſame quantity of biſmuth, melt them together in a clean crucible, and ſtir the maſs repeatedly with a clean iron rod till the two metals are accurately mixed. Then remove the crucible from the fire, and when its contents are upon the point of becoming ſolid, pour in an ounce and a half of warmed quickſilver, ſtirring it as before. Previouſly to uſing this alloy, it muſt be ground in a ſtone or earthenware mortar with white of egg and ſpirit varniſh, and in this ſtate applied to the intended work. When dried it may be burniſhed in the uſual manner, and has then very much the appearance of ſilver.[a]

ARGIL NATIVE.[b] *Alumine native. Reine Thonerde. Argilla pura* Werner.

This mineral is of a ſnow-white, or yellowiſh-white colour: it is found in various ſized kidney-form maſſes; preſents a fine grained earthy fracture; is ſomewhat tranſlucid at the edges, and becomes ſtill more ſo when ſoaked in water; is ſoft to the touch, but not unctuous; ſtains the fingers; adheres ſlightly to the tongue, and is eaſily broken, being almoſt friable. Sp. gr. according to Bergman, 1.305.

When examined by a microſcope, this ſubſtance is found to conſiſt of minute tranſparent cryſtals, in the form of compreſſed priſms, terminated by blunted pyramids.

By expoſure to a ſtrong heat it loſes two-thirds of its weight. It is almoſt wholly ſoluble in nitric or ſulphuric acid without effervеſcence, and from the experiments of T. Sauſſure,[c] appears to conſiſt of alumine, of ſulphat of lime, of a little combuſtible vegetable matter, and of a ſubſtance which bears a near reſem-

[d] Pelletier's Mem. de Chimie, vol. i. p. 380.
[b] Widenmann, Lenz, Brochant.
[a] Encycloped. method. art. Argent. muſicum.
[c] Journ. de Phyſique, vol. 52. p. 287.

blance to glucine, being ſoluble in carbonated ammonia.

In has hitherto been only found in the garden of the college of Halle, in Saxony, and is conſidered by many mineralogiſts as not properly a natural production.

ARGILLITE. See THONSCHIEFER.

ARGILLACEOUS *Earth*. A term given by ſome to pure CLAY or ALUMINE.

ARGILLE KAOLIN. See CLAY *Porcelain*.

ARGILLE GLAISE. See CLAY *Potters*.

ARGILLE SCHISTEUSE. ARGILLACEOUS SCHISTUS. See THONSCHIEFER.

AROMA, or *Spiritus Rector*, is applied to that part of odorous bodies which affects the organs of ſmell, and is ſuppoſed by ſome to be a peculiar principle. The ſubtlety of this principle, and the difficulty, amounting almoſt to impoſſibility, of eſtabliſhing its identity, make this enquiry more curious than uſeful. All that can be ſaid on the ſubject lies in a ſhort compaſs, and will be noticed under the article OIL *Eſſential*, to which it may with propriety be referred.

ARRAGONIT.[a] *Exzentriſcher Kalkſtein*, Emmerling. *Arragonite*, Hauy and Brochant.

The colour of this mineral is greyiſh, or greeniſh white, or pale mountain green, but the centre of each cryſtal is generally violet blue and browniſh red. It cryſtallizes in hexahedral priſms (priſmatique of Hauy), the baſes of which, though plane and compact, are without luſtre, and the ſides are ſtriated longitudinally, and occaſionally are ſomewhat concave; alſo in hexahedral priſms, the baſes of which are rough with ſmall wedge-ſhaped points (cuneolaire of Hauy); or in rounded and deeply ſtriated maſſes (cylindroide of Hauy). The cryſtals are of moderate ſize, and are found either ſingle or in groups: each of thoſe that belong to the firſt variety may be conſidered as an aſſemblage of rhomboidal priſms, every one of which incloſes another priſm in ſuch a poſition that their axes croſs nearly at right angles, as is obvious from the croſſing of the ſtriæ, and eſpecially by a kind of moſaic in the centre of the priſm, repreſenting four triangles united round a common point; two of which are of a violet colour, and have their baſes parallel to the ſides of the priſm, while the two contrary ones are of a pale whitiſh colour. This diſpoſition becomes very ſtriking when the priſms are ſawn aſunder in the direction of their axes and the ſurfaces poliſhed. The arragonit, externally, is but little ſhining; internally, however, it diſplays a very brilliant vitreous luſtre: the fracture is obſcurely foliated. It ſcratches calcareous ſpar, is ſemitranſparent, has a double refraction. Sp. gr. 2.94.

When pulverized and ſpread on hot coals, it gives out a feeble phoſphoreſcent light. Before the blowpipe it decrepitates, and at length is calcined like calcareous ſpar. It is ſoluble with effervеſcence in nitric acid. Klaproth, Vauquelin and Thenard have made ſeparate analyſes of it with great care, but have diſcovered nothing in its compoſition except lime and carbonic acid, in the ſame proportions as conſtitute the pureſt calcareous ſpar.

The arragonit was firſt ranked as a diſtinct ſpecies by Werner, and obtained its preſent name becauſe it was originally diſcovered in Arragon and Valencia, where it is imbedded in fibrous and granular gypſum: it has ſince been found in the Pyrennees, and at Leogang, in the country of Saltzburg, in a ſhattery argillaceous rock, or in quartz, accompanied by calcareous ſpar, and cupreous and arſenical pyrites.

This mineral deſerves attention, as being one of the very few whoſe external and cryſtallographical characters are at variance with the reſults of its chemical analyſis. The primitive form of calcareous ſpar is a rhomboid, the ſolid angles of which meaſure 104°. 28′. but the arragonite is diviſible only in two directions, and the inclination of its joints is 116°.

ARSENIC is a ſubſtance of very frequent occurrence, being found in combination with almoſt every other metal, as well as with ſulphur and lime: the four following ſpecies however, are the only ones that by the common conſent of Mineralogiſts are ranked as ores of this metal, the reſt being conſidered as arſenicated ores of ſilver, copper, cobalt, &c.[b]

Sp. I. Native Arſenic. *Gediegener Arſenick. Arſenic natif.*

The colour of this mineral when newly broken, is a light lead-grey, paſſing into tin-white; but the ſurface by expoſure to the air becomes yellow, then blackiſh grey, and at length almoſt black.

It occurs generally in maſs, but ſometimes diſſeminated: it does not form cryſtals, but kidney-ſhaped or cluſtered maſſes (hence called teſtaceous arſenic); or is found in plates or curious pieces. Its ſurface is rough or granular, with little or no luſtre; internally it exhibits a ſlight metallic luſtre. It acquires a poliſh by

[a] Hauy, Traité de Mineralog. vol. iv. p. 337. Emmerling, Lehrbuch der Mineralog. vol. ii. p. 681.

[b] Emmerling, Brochant, Kirwan, Hauy.

friction, and emits an alliaceous odour: it is half-hard and brittle. Specific gravity, according to Briſſon, 5.724—5.763.

When expoſed to the blowpipe it fuſes without difficulty, giving out a copious white vapour, and the peculiar odour of arſenic: by an increaſe of heat it burns with a bluiſh flame, and is wholly diſſipated.

Native arſenic has not been accurately analyſed, but beſides arſenic, it appears always to contain a little iron (to which its fuſibility is owing), and occaſionally a very ſmall portion of gold or ſilver.

This mineral is found only in the veins of primitive mountains, accompanied by red ſilver, realgar, galena, ſpecular cobalt, kupfernickel, pyrites, &c. It occurs in the mines of Freyberg, in Saxony; at Geiſberg, in Carinthia; at Nagyag, in Tranſilvania; and St. Marie aux Mines, in France.

Sp. II. Arſenical pyrites, Marcaſite, or Miſpickel. *Arſenick-kies. Fer arſenical.*

The colour of this mineral, when recently broken, is a ſilvery white, but it ſoon tarniſhes to yellowiſh, greyiſh, bluiſh or irideſcent. It is met with in maſs, diſſeminated, and not unfrequently cryſtallized. Its figures are, 1. A perfect, ſomewhat oblique-angled quadrilateral priſm. 2. The ſame terminated by dihedral ſummits. 3. The ſame priſm with convex or concave lateral faces. 4. A very acute octahedron. 5. Lenticular cryſtals. The ſize of the cryſtals varies from moderately large to very minute or acicular. The lateral faces of the priſms are always ſmooth and brilliant; the ſummits are tranſverſely ſtriated. Internally the luſtre is ſhining and metallic. Its fracture is uneven and granular. It is hard and brittle. Sp. gr. according to Hauy, 6.52.

When ſcratched or ſtruck with the hammer, the arſenical pyrites emits a ſtrong alliaceous odour. Before the blowpipe it gives out a copious white vapour of oxyd of arſenic, a ſmall portion of earth and oxyd of iron remaining behind in the form of an infuſible powder, or of a brittle globule, if the heat has been conſiderable.

This mineral has not been accurately analyſed, or rather appears to contain arſenic, iron, and ſulphur, in variable proportions; mixed with which is occaſionally found from one to ten per cent. of ſilver.

It is found in almoſt all metalliferous primitive mountains; but the variety containing ſilver has hitherto been met with only at Freyberg and Braunſdorf, in Saxony.

Sp. III. Sulphuret of Arſenic.

This ſpecies is generally, though perhaps unneceſſarily, divided into two varieties, which however appear to paſs into each other, ſo as to render it difficult to aſſign the limits of each; we ſhall therefore follow the example of Hauy, in referring all the cryſtalline forms to the firſt variety.

Var. 1. Realgar. *Rothes Rauſchgelb. Arſenic ſulphuré rouge.*

Its colour is a bright Aurora red, paſſing on one ſide into ſcarlet, on the other to light orange. It is found rarely in maſs, more frequently diſſeminated or inveſting, but moſt commonly cryſtallized. The primitive form of its cryſtals appears to be the ſame with that of ſulphur, namely, the long octahedron, with ſcalene triangular faces; ſometimes a quadrilateral priſm is interpoſed between the pyramids of the octahedron, and other varieties are deduced from the truncature of the ſolid angles and the bevilling of the ſides of the priſm. The cryſtals are generally ſmall and difficult to determine: they exhibit, both externally and internally, a brilliant luſtre, between vitreous and waxy. The fracture is uneven granular, paſſing into minute conchoidal. It is commonly tranſlucid, but occaſionally alſo ſemitranſparent or opaque. The colour of its ſtreak is orange yellow: it is very tender, brittle, and may be eaſily broken by the nail. Sp. gr. from 3.2 to 3.3. It is idioelectric, acquiring the reſinous electricity by friction.

Before the blowpipe it melts eaſily, burns with a blue flame, and exhales a ſulphureous arſenical odour, and is almoſt entirely volatilized. It loſes its colour by digeſtion for a ſhort time in nitrous acid. It has never been accurately analyſed, but conſiſts for the moſt part of arſenic and ſulphur.

Realgar occurs native in the vicinity of Etna and other volcanoes, and in the primitive mountains of Germany, Swiſſerland and Hungary. The ſubſtances by which it is uſually accompanied are native arſenic, red ſilver, and galena.

Var. 2. Orpiment. *Gelbes Rauſchgelb. Arſenic ſulphuré rouge.*

Orpiment differs from realgar in the following particulars. Its colour is a bright lemon yellow, paſſing into gold yellow and aurora-red. It is found diſſeminated or in maſs: its internal luſtre is very brilliant, between waxy and ſemimetallic: its fracture is ſtrait or curved-foliated. Sp. gr. 3.4.

It is always found in ſtratified mountains, accompanied by clay, quartz, &c. and appears

to be a mineral of late formation. It is procured from the Bannat, from Servia, from Nagyag in Tranſilvania, and Felſobanya in Hungary. The Romans procured the beautiful bright gold coloured orpiment from Syria, and eſteemed it highly as a pigment.

Sp. IV. Native White Arſenic. *Naturlicher arſenick-kalk. Arſenic oxydé natif.*

Its colour is ſnow-white, or yellowiſh reddiſh or ſnow white, or ſmoke grey. It is commonly found in the ſtate of a friable earthy cruſt, on the ſurface of other minerals; it is alſo occaſionally met with ſtalactitic, cluſtered, or in minute bundled capillary cryſtals. In the earthy ſtate it is opaque, but when cryſtallized is tranſlucid. It is friable and very brittle. Sp. gr. 3.7.

When expoſed to the blow pipe it is almoſt entirely volatilized in the form of a white vapour, accompanied by the characteriſtic odour of arſenic; the ſmoke-grey variety approaches to the metallic ſtate, and therefore, when heated, burns with a very pale blue flame. It is ſoluble in fifteen times its weight of boiling water, leaving behind ſcarcely any reſiduum, and is probably a pure oxyd of arſenic.

This mineral is of very rare occurrence, having been met with as yet only in the cobalt mines of Bohemia and Saxony, and on the ſurface of native arſenic in Tranſilvania and Hungary.

White Arſenic, when in its pureſt ſtate, appears as a beautiful white, ſonorous, vitriform maſs, very brittle, and eaſily reduced to powder. When recently prepared it is conſiderably tranſparent, but becomes opake by keeping. It is prepared in the large way by a ſecond ſublimation of the impure arſenic, obtained in the roaſting of the arſenical ores. M. Fragoſo de Sigueira gives the following account of the method adopted in Bohemia.[c]

The ſubliming veſſels are ſtrong ſquare boxes of caſt iron, furniſhed with conical heads of the ſame material, cloſely luted to them with clay. The ſquare boxes are diſpoſed in a large brick area, which is heated by the flues of two furnaces placed a little below them. When red-hot, the impure arſenic is laded into the boxes by fifteen pounds at a time, where it melts, and in about an hour after it begins to ſublime into the conical head. When no more riſes, another fifteen pounds is put into the veſſel, and treated as before; and this ſucceſſive addition is continued till about 150 pounds of arſenic have been uſed to each veſſel, the ſublimation of the whole of which quantity laſts about 12 hours. When cold, the workmen take off the conical head, and carry it with its contents to another place, where they break off with hammers the ſublimed arſenic, ſeparating any impurity for a ſecond operation.

The yellow glaſs of arſenic, or artificial orpiment, is prepared in the ſame manner with the ſame apparatus, but for this the arſenic is previouſly mixed with half its weight of ſulphur. In either caſe the heat ſhould be maintained all the while uniformly red, ſo as to keep the materials in the lower veſſel always in fuſion. When theſe are tolerably pure, almoſt the whole riſes in the ſublimation. It is remarkable that the ſimple precautions taken to have a free current of air, and to avoid breathing the duſt of the arſenic when the veſſels are filled, are ſufficient to preſerve the health of the workmen employed about this hazardous metal.

The rough material of this proceſs is the oxyd of arſenic, obtained by roaſting the TIN and COBALT ores, and twice torrefied before it is uſed for ſublimation. If theſe precautions are not obſerved, the arſenic remains yellow and grey inſtead of white.

As arſenic is a metal of little value in itſelf, and ſo detrimental to moſt other metals, by rendering them brittle and unmalleable, the analyſis of the arſenical ores, with a view to the quantity of this metal, is a matter rather of curioſity than utility. When required, ſeveral methods have been propoſed.

In the ores of ſeveral metals ſimply mineralized by arſenic, the quantity of this metal may be eſtimated roughly by the loſs which the ore undergoes on roaſting. The arſenic which is volatile in a red heat, flies off in ſtrong garlick-ſmelling fumes. This way, however, is very inaccurate, for all the arſenic cannot be driven off by mere heat, nor is the reſidue always in the ſame ſtate of oxidation after as before roaſting, and conſequently its weight may have altered, independant of the loſs of arſenic.

For the analyſis of the native arſenic, Bergman recommends to diſſolve it in four times its weight of nitro-muriatic acid, ſlowly evaporate it as long as it remains clear, and then, by the addition of water, the arſenical oxyd will alone be precipitated. This way, however, is not accurate, as ſome of the arſenic remains in ſolution, and a ſmall portion will probably be acidified by the nitrous acid, and form a compound with iron, beſides other combinations. Zinc will alſo precipitate the arſenic from its ſolution in a reguline ſtate.

[c] Journ. Phyſ. tom. 1.

In the ſulphurets of arſenic, the arſenic is ſlowly diſſolved in marine acid, with occaſional addition of the nitrous. The ſolution proceeds languidly, till at laſt only the ſulphur is left untouched and in its natural ſtate. This, collected and weighed, will indicate the quantity of arſenic in the ſolution. Some objection, however applies to this method, as part of the ſulphur may alſo be acidified if the proceſs is not carried on with extreme caution, but on the whole it appears an uſeful method.

The roaſting of the arſenical ores is a tedious proceſs, and requires ſome management. They ſhould always be previouſly ground to powder, mixed with charcoal, or better with ſaw-duſt, and kept at a low red-heat for ſeveral hours. The above admixtures render the arſenic much more volatile, by keeping it in the reguline ſtate (at which it flies off with leſs heat than in any other form), and by dividing it they prevent it from clotting and running in lumps by fuſion. Where the mere ſeparation of the arſenic is required (as in eſtimating the quantity of iron in miſpickel), the following way will be found by much the moſt convenient and the ſhorteſt.[a] Add to the powdered ore dilute nitric acid, and digeſt with a gentle heat. This will diſſolve all the arſenic and iron, whilſt moſt of the ſulphur, with the ſiliceous reſidue, will remain undiſſolved. Pour off the nitrated ſolution, mix with it about twice as much powdered charcoal as the quantity of ore employed, and evaporate nearly to dryneſs. Put the reſidue in a tall crucible, and apply a briſk red heat for about ten minutes, by which time the arſenic will be almoſt entirely driven off in copious fumes, and the reſidue will conſiſt of little elſe than charcoal and oxyd of iron. Spread this upon a heated tile, till the charcoal is moſtly burned off, by which any arſenic ſtill adhering will be diſſipated, and the remaining oxyd of iron may be reduced, or eſtimated in the way mentioned under that metal. The nitrous acid is preferable to the muriatic in this proceſs, as the latter, when ſtrongly heated, volatilizes part of the iron and renders the aſſay incorrect.

As a general rule in attempting the analyſis of the arſenical ores by nitric or nitro-muriatic acid alone, it ſhould be obſerved that where the object is a ſimple ſolution of the arſenic, with a view to ſubſequent precipitation, either by water or an alkali, no more acid ſhould be employed than is abſolutely neceſſary; ſince arſenic is a ſubſtance capable of compleat acidification by the nitrous acid in ſufficient quantity, and when acidified, it is no longer precipitable by water or by alkalies, but acts quite a new part in the mixture.

Miſpickel, a native alloy of arſenic and iron, is analyzed by Bergman by the nitro-muriatic acid. This will indeed diſſolve both iron and arſenic, but by ſlow digeſtion it may be made to take up all the iron before the arſenic is much acted on.

But as in every ſolution of arſenic by nitric acid, ſome arſenic acid will probably be generated, another way of analyſis is pointed out which is by far the moſt accurate. It is the compleat acidification of the arſenic in the firſt inſtance, and afterwards uniting it with lead, which forms an inſoluble compound, the proportions of which appear invariable. The following is M. Chenevix's method of analyſing miſpickel, which may be applied (with proper allowances) to eſtimating the quantity of arſenic in any ore or mixture. Reduce the ore[c] to very fine powder, and compleatly acidify it by nitric acid, ſaturate the whole acid with an alkali, which will form arſeniated and perhaps a little nitrated alkali, then add nitrated lead as long as any precipitation appears. The precipitate is arſeniated lead, 100 parts of which, dried at a low red heat, contain 33.2 of arſenic acid, of which the reguline metallic part may be reckoned at 22 parts. If ſulphur be combined with arſenic, part of it will alſo be acidified in the proceſs, and an inſoluble ſulphat of lead will alſo be formed along with the arſeniat. Theſe, however, are ſeparated by weak nitric or by acetous acid, the arſeniat of lead being ſoluble in this menſtruum, but not the ſulphat of lead. Hence the difference of weight between the precipitate before and after treatment with the latter acid, will ſhew the proportions of the arſeniat and ſulphat of lead.

Regulus of Arſenic, or *Arſenic*, properly ſo called, may be prepared in ſeveral ways, and the moſt convenient ſubſtance for procuring it is the common white arſenic of the ſhops. This is a ſimple oxyd of the metal, and it may be reduced by heating with any carbonaceous matter; but as arſenic in a metallic ſtate is even more volatile than its oxyd, the common mode of fuſion will not anſwer, as the metal will eſcape in denſe fumes as faſt as it is produced. Sublimation muſt therefore be uſed, the white arſenic and its reducing flux being heated together in cloſe veſſels, and the fumes of the reguline arſenic being condenſed on a cooler part of the ſame or an adjoining veſſel. The

[a] Own Experiments.

[c] Phil. Tranſ. vol. 91.

following mode is ſimple, eaſily performed, and makes an intereſting experiment in the ſmall way. Mix white arſenic with oil into a maſs of the conſiſtence of ſoft dough, drop it into a dry Florence flaſk, taking care not to ſoil the neck as the mixture paſſes down, put the veſſel on charcoal, either naked or in a ſand pot, and heat gradually. When hot enough, the oil begins to burn, and partly flies off in thick fumes, blackening the neck of the flaſk; theſe fumes ſoon acquire a ſtrong and moſt offenſive odour, ſomewhat like garlick, owing to the eſcape of part of the arſenic, which ſhould be carefully avoided by the operator. The whole flaſk now becomes obſcure, ſo that the proceſs can only be judged of by the copiouſneſs of the fumes, which preſently are ſeen to depoſit black films on the neck of the flaſk, like ſoot, but ſymmetrically arranged. The heat ſhould be ſlowly raiſed, ſo as to redden the bottom of the flaſk, and when the fumes ſcarcely ariſe, and the hotteſt part of the veſſel is found to be nearly empty, the whole may be allowed to cool. On breaking the veſſel carefully, nothing is found in the bottom, as far as it was red-hot, but a light ſpongy coal, the remains of the oil; all above it, to the very top of the neck of the flaſk, is lined with a light black-grey cruſt, beneath which, immediately adhering to the glaſs and taking the impreſſion of its ſhape, is a brittle black ſhining metallic ſubſtance, which is the regulus of arſenic. The neck of the flaſk is alſo covered with a number of beautiful greeniſh tranſparent pyramidical cryſtals of arſenic, oxydated by the acceſs of air through the mouth, which in condenſing aſſume this elegant form. To obtain the regulus more completely, the whole of the contents of the flaſk ſhould be mixed together by rubbing, and put into a freſh flaſk without addition, and again ſublimed ſlowly, ſtopping the mouth with paper, as there is now little need of giving vent to any fumes during the proceſs. The ſublimed regulus is now as perfect as it can be obtained, often cryſtallized, and exhibits every mark of a true metal.

The old method of preparing this metal was the following. White arſenic four parts, black flux two parts, iron filings and borax each one part, were put into a covered crucible, and haſtily fuſed, after which the veſſel was immediately removed from the fire. Much of the arſenic was diſſipated in this way, but at the bottom of the crucible a blueiſh white regulus was found, conſiſting of reguline arſenic, combined with the iron into a hard alloy, the uſe of the latter metal being only to detain the arſenic and prevent its volatilization.

This alloy tarniſhes much ſooner than the pure regulus. By ſublimation in cloſe veſſels, the arſenic riſes much ſooner than before, but is thought ſtill to carry up with it a ſmall portion of iron, though the greater part is left behind.

For the moſt delicate chemical purpoſes, a beautiful regulus may be made by mixing arſeniat of potaſh with about one-eighth of charcoal, and ſubliming in a cloſe glaſs veſſel ſlowly heated to redneſs. The regulus is beautifully brilliant and cryſtallized.

The regulus is equally prepared in the large way by ſublimation, in earthen veſſels, of the oxyd, mixed with a reducing flux.

Arsenic when pure has the following properties: its colour is between a tin-white and lead-blue, which by expoſure to air readily tarniſhes, the later as it is the purer, and becomes firſt yellow, and then black and pulverulent; but it may be kept under water unaltered. Slowly ſublimed in cloſe veſſels, it cryſtallizes in octahedrons: its ſpecific gravity 8.308 to 8.310. Its hardneſs is about equal to that of copper, but it is quite brittle and very eaſily pulverizable. Of all metals arſenic is the moſt volatile by heat, for it begins to riſe in fumes at about 356° Fahrenheit, that is, long before it melts, ſo that it can hardly ever be ſeen in a ſtate of fuſion. Theſe fumes in the open air are denſe, white, and exhale a very peculiar and noxious ſmell, ſomewhat reſembling garlick, which circumſtance forms one of the readieſt teſts for this metal or its oxyd. Arſenic ſuddenly heated to redneſs, by being thrown into a very hot crucible, takes fire, and burns with a whitiſh-blue flame, yellow at the edges. This combuſtion is alſo finely ſhewn by projecting ſome arſenic in fine powder, into a flaſk full of oxymuriatic gas: it takes fire inſtantly and burns with a beautiful flame.

The condenſed fume of arſenic heated in cloſe veſſels is the regulus unaltered, but in the open air it condenſes into a white, ſometimes yellowiſh, mealy ſubſtance, which is the *White Oxyd of Arſenic*, ſimilar to the common *white arſenic* of the ſhops. This oxyd is alſo volatile *per ſe*, but requires for the purpoſe a greater heat than the reguline arſenic, and when mixed with earthy ſubſtances it acquires ſo much fixity as to prove a moſt powerful flux. See Glass.

White oxyd of arſenic is more ſoluble in water than any other metallic oxyd. About 80 parts of cold water diſſolve one part of white arſenic, but no more than 15 or 16 of boiling

water are required. Much is depoſited by cooling, but much more is left in the ſolution than cold water alone could take up. This ſolution is clear and colourleſs, has a ſharp warm taſte, very permanent to the tongue and ſomewhat ſweet, and exciting nauſea. It reddens litmus tincture, but does not cauſe any effervescence with carbonated alkali or earth. It does not alter ſyrup of violets.[f] When ſlowly evaporated, the oxyd ſeparates in minute cryſtals, which are long, many-ſided, truncated at both ends, and often radiated or feathery. The moſt regular form ſeems to be a three-ſided pyramid. Theſe cryſtals expoſed to the air fall into a mealy powder, in which they differ from the native and ſublimed cryſtallized oxyds, which are permanent.

Alcohol diſſolves about $\frac{1}{80}$ of its weight of white arſenic. This oxyd is entirely volatile when heated without addition, and ſublimes unaltered, and in this reſpect it differs from all other metallic oxyds, moſt of which are permanent, and flow into a coloured glaſs by intenſe fire. To ſublime the white oxyd of arſenic for experiment,[g] a common phial ſhould be half filled with the oxyd, looſely ſtopped, and put into a crucible with ſand, no deeper than the height to which the bottle is filled. A briſk heat may be then applied, and the oxyd riſes and condenſes on the upper part of the bottle, but it requires a long continued heat to ſublime the whole. The upper part of the ſublimate is uſually in a vitriform ſtate, but very regular cryſtals may be found diſperſed through it, generally octahedral. The heat at which the oxyd begins to evaporate is about 383° Fahr.[h] or ſomewhat higher than the evaporating point of the regulus. The fumes are equally ſtrong-ſmelling and garlicky, and extremely noxious to breathe. The oxyd, mixed with borax or ſoda, and heated with the blowpipe, runs into a yellow glaſs, ſo that it is moſtly kept down by the ſaline flux. The ſpecific gravity of the ſolid vitriform oxyd of arſenic is about 5.03; that of the cryſtallized, about 3.7.

From the ready ſolubility of this oxyd, and its ſtrong ſenſible properties, it was long conjectured to poſſeſs ſomewhat of an *acid* nature. The admirable experiments of Scheele have fully cleared up this point, and have ſhewn that arſenic is capable of complete acidification, forming a very ſingular ſubſtance, which we ſhall preſently mention, and that the white oxyd is in a ſtate intermediate between the regulus and the perfect acid. Some chemiſts have therefore termed it the arſen*ious* acid, conformably with the new nomenclature, but as the acid properties are ſcarcely ſenſible, the term *white oxyd of arſenic* is preferable. The component parts of this oxyd are, according to Prouſt, 100 parts of arſenic to 33 of oxygen. The mode of reduction has been deſcribed in the preparation of the regulus of arſenic.

We proceed to the effect of acids and other reagents on arſenic and its oxyd. The peculiar properties of the arſenic acid will afterwards be noticed, but it ſhould be obſerved, that the tendency of arſenic or its oxyd to complete acidification is ſo great, that many acids, when acting ſtrongly upon this metal, not only diſſolve it, but proceed to convert it, totally or partially, into arſenic acid. Hence the deſcription of the preparation of this acid is inſeparable from that of the operation of the acids upon the metal or its oxyd.

Sulphuric acid, when hot, acts on arſenic ſlowly.[i] Sulphureous acid is given out, and ſome ſulphur ſublimes. The undiſſolved reſidue reſembles the white oxyd. White oxyd of arſenic ſoon diſſolves in boiling and concentrated ſulphuric acid, and a granular cryſtalline maſs is left, which however is not a perfect ſulphat of arſenic, as it is partly mixed with arſenic acid. By repeated abſtraction of two parts of ſulphuric acid to one of the oxyd, and at laſt by heating the retort red hot, the reſidue no longer ſublimes like white arſenic, but melts to a cryſtalline maſs, which in the air becomes opake, and deliqueſces into a four liquid, conſiſting almoſt entirely of arſenic acid generated in the proceſs. This however is tedious and difficult. By the blowpipe on charcoal it returns to the ſtate of white oxyd.

Muriatic acid diſſolves arſenic only when heated, but then eaſily, and with the emiſſion of arſeniated hydrogen gas. About a third of the weight of the acid is diſſolved. The greater part ſeparates by cooling into cryſtalline grains. The white oxyd is more readily ſoluble in this acid. The cryſtallized muriated arſenic readily ſublimes when heated. The ſaturated ſolution depoſits almoſt the whole of its oxyd by the affuſion of water, a method ſometimes uſed in analyſis. A ſingular combination of muriatic acid, with oxyd of arſenic, termed *butter of arſenic*, is formed by diſtillation. This will be deſcribed when noticing the arſenic acid.

Nitric acid, even diluted, attacks arſenic violently when heated, and nitrous gas is given out in abundance. The metal is firſt changed

[f] Pelletier. [g] Ibid. [h] Bergman. [i] Gren.

to the white oxyd in this proceſs, and by more acid is diſſolved, and depoſits on cooling a granular nitrated arſenic. Water alſo precipitates the oxyd from the ſaturated ſolution. The cryſtals of this ſalt are cubical or octahedral. When heated alone, the remaining nitrous gas is driven off from the cryſtals, and in the proceſs they appear to paſs to the ſtate of arſenic acid, and thus to acquire fixity in the fire, this property being a ſtriking mark of difference between the arſenic acid and the regulus or its oxyds. An exceſs of nitric acid converts arſenic or its oxyd entirely into arſenic acid, as will afterwards be mentioned.

The nitro-muriatic acid may be made either a perfect and ſimple ſolvent of arſenic and its oxyd, or a method of compleatly oxygenating it and converting it to arſenic acid. Nitro-muriatic acid ſlowly digeſted on arſenic or its oxyd, diſſolves it with little alteration, and the oxyd is moſtly precipitable by water, or eſpecially by alcohol: whereas a different management of the two acids compleatly acidifies the arſenic.

Fluoric acid has no action on arſenic. It diſſolves the white oxyd into a cryſtalline fluat of arſenic, but little known.

Boracic acid acts only on the oxyd. Theſe ſubſtances will unite by fuſion, and a borat of arſenic is formed, [k] partly in powder, partly in arborescent ſpiculæ, when diſſolved and cryſtallized by evaporation.

The other acid ſalts of arſenic are but little known. In general theſe acids have no action on arſenic, but diſſolve the oxyd (which indeed is extremely ſoluble in almoſt every menſtruum), and form cryſtallizable combinations.

Arsenic Acid. We are indebted to the admirable ſkill and ſagacity of Scheele for our firſt knowledge of this acid, and of moſt of its known combinations. To prepare it, put 2 ounces of white arſenic into a retort, with 7 ounces of muriatic acid, and diſſolve the arſenic by boiling: then, when ſtill hot, add $3\frac{1}{2}$ ounces of pure nitrous acid, and again heat. The mixture ſoon foams, and red nitrous vapour eſcapes. When this laſt appearance has ceaſed, add another ounce of white arſenic, diſſolve by boiling as before, and then add $1\frac{1}{2}$ ounce additional of nitrous acid, whereby the ſame ebullition and eſcape of red vapour will be renewed. Diſtill the whole to dryneſs, till a white maſs remains in the retort, which ſhould be gradually heated to redneſs. When the retort is cold, break it, and the dry ſubſtance within is the *concrete acid of arſenic*, which is tranſparent when hot, but on cooling becomes white and opake. Diſſolved in water, it forms a ſtrong acid liquor, leaving behind ſome ſiliceous earth, acquired from the retort, which is much corroded in the proceſs. The concrete acid alſo deliqueſces by keeping in a moiſt place, and runs into the ſame acid liquor.

In the above proceſs, the uſe of the muriatic acid is to keep the arſenic diſſolved whilſt the nitrous acidifies it. If economy of the diſtilled nitro-muriatic acid be no object, the ſecond addition of white arſenic and nitric acid may be ſpared, and the whole taken at once, that is, 3 parts of white oxyd, diſſolved in 7 parts of muriatic acid, and 5 parts of nitric acid, added when the ſolution is effected. Towards the end, when the arſenic acid is nearly dry, the expulſion of the laſt-adhering portion of nitric acid is attended with a boiling up, which is apt to carry with it part of the acid of arſenic, and thus an error ariſes in eſtimating the quantity produced. To prevent it, Prouſt [l] gently ſhakes the retort at this period with a rotatory motion, which much promotes the eaſy volatilization of the nitrous acid, prevents the ebullition, and the metallic acid thickens immediately. In applying the red heat to dry it thoroughly, it ſhould be continued till a few cryſtalline ſtreaks of ſublimed oxyd of arſenic appear in the top of the retort; that is, till the acid begins to be ſpontaneouſly decompoſed by heat. It is then quite pure.

A ſpeedier way of preparing this acid is the following: [m] mix together in a crucible 2 parts of muriatic acid of 1.2 of ſpecific gravity, 8 parts of white oxyd of arſenic, and 24 parts of nitric acid of 1.25 ſpecific gravity. Evaporate to dryneſs, and expoſe the maſs to a ſlight red heat. The quantity of the acids recommended varies conſiderably, but no harm can enſue from uſing an exceſs of them, beyond the loſs of acid; and on the other hand, if too little be employed for acidifying all the arſenic, it is probable that all the imperfectly oxidated portion will fly off in the heat, and the arſenic acid left behind will be equally pure.

Arſenic acid has but little taſte till previouſly diſſolved in water, when it is extremely ſour. Its ſpecific gravity when dry is about 3.391. Compared with arſenic, its oxyds, its ſulphuret, or ſaline compounds, it is remarkably fixed in the fire, all the other arſenical preparations readily ſubliming it leſs than a red heat. In a high heat, however, the acid itſelf is partly decompoſed, and by loſing oxygen a portion of

[k] Gren. [l] Journ. de Phyſ. tom. 49. [m] Thomſon's Chemiſtry.

white oxyd is generated, which ſublimes. If this is done in a crucible, the clay of this veſſel will be ſtrongly attacked by part of the acid when red hot, forming a permanently fixed glaſs, but by repeated ſolution in water and filtration, moſt of the clay is again ſeparated. When this acid is long heated to redneſs in a glaſs retort, this laſt becomes entirely corroded, ſo as when cold to crumble between the fingers. According to Prouſt, and other confirming calculations, 100 parts of arſenic in the metallic ſtate acquire 33 of oxygen when converted into the white oxyd, and 20 additional oxygen when completely acidified. So that 100 parts of the white oxyd are compoſed of about 75 of arſenic and 25 of oxygen; and 100 parts of the acid contain 65.4 of arſenic and 34.6 of oxygen.

The action of the oxygenized muriatic acid on arſenic is very ſtriking. It was firſt noticed by Scheele. Let the vapour of this acid (prepared from muriatic acid diſtilled from oxyd of manganeſe) be received into a veſſel containing the white oxyd of arſenic and water. The acid vapour is ſpeedily abſorbed, and ſome hours afterwards the arſenic will be diſſolved, forming two liquid ſtrata, immiſcible with each other. Let theſe be rediſtilled from a clean retort, gradually heated to redneſs, and the product will again be two ſeparate liquids, of very different weight. The loweſt and heavieſt is a peculiar combination of muriatic acid with arſenic highly oxydated, but not to complete acidification, and from its denſity is called *Butter of arſenic*. The upper liquid is acid of arſenic generated by the action of the oxymuriatic acid, and diſſolved in water with a portion of muriatic acid. A freſh diſtillation cauſes the *butter* to riſe, and to paſs into the receiver in the form of a heavy oil, whilſt the perfect acid of arſenic remains, and may be obtained pure by diſtillation to dryneſs, and gently reddening the retort. The acid thus obtained in no reſpect differs from that prepared by the nitric acid.

Butter of arſenic is produced in moſt caſes where, during diſtillation, arſenic or its oxyd is in contact with muriatic acid at the moment of its evolution, together with an exceſs of oxygen. It is ſtill uncertain whether the muriatic acid firſt combines with the oxygen previous to its action on the metal, and what is the exact ſtate of combination of ingredients in the metallic butter. If orpiment (or ſulphuret of arſenic) be diſtilled with triple its weight of corroſive ſublimate of mercury, two liquids paſs over into the receiver, and by urging the heat, cinnabar is ſublimed. Theſe two liquids are equally obtained (but without the cinnabar) by diſtilling in a ſand-bath 1 part of white arſenic with 3 of common ſalt, and $1\frac{1}{2}$ of calcined vitriol. The heavieſt liquor, which is thick and brown, but tranſparent, comes over firſt; the lighteſt, which is yellow and thin, ſucceeds. The heavy liquid is the *butter of arſenic*, which, expoſed to air, ſends out a white fume, and gradually abſorbs the atmoſpheric moiſture, whereby the diſſolved oxyd of arſenic is ſlowly precipitated.[a] An inſtant ſeparation of the white oxyd in fine powder takes place on adding water, as is the caſe with the other metallic butters. The fumes of the arſenical butter are pungent, like ſulphureous acid. The upper thin liquid (called by ſome the *oil of arſenic*) equally lets fall a white oxyd on adding water, or alcohol, or alkalies, and with the latter it effervesces. By ſlow evaporation cryſtals appear, ſimilar in properties to thoſe of the common muriated arſenic, but extremely volatile by heat. When corroſive ſublimate is uſed in the preparation, all the mercury appears to remain in union with the ſulphur of the orpiment, forming the red ſulphuret of mercury or cinnabar. The preciſe difference between theſe two ſingular liquids is not well known, but they appear to be little elſe than muriatic acid in ſome form of union with oxyd of arſenic, and more abundant in the *butter*; and hence more of this, in proportion to the oil, is obtained, by letting the materials ſtand together intimately mixed, for ſome time before diſtillation. Dilute muriatic acid acts merely as water in ſeparating the oxyd from both the oil and the butter; the ſtrong acid ſimply remains immiſcible with the butter. Arſenic decompoſes corroſive ſublimate equally with orpiment, and the products are, beſides the butter, calomel and ſome running mercury.[b] The oxyd of arſenic, on the other hand, produces no change on corroſive ſublimate, and on ſublimation they each riſe unaltered.

Arſenic acid forms a variety of intereſting compounds with alkalies and metallic oxyds, and in this point of view it requires a ſeparate notice. Several of theſe ſalts will be deſcribed in the ſucceeding article of ARSENIATS. In forming many of theſe compounds the acid remains unaltered, following its affinities as an acid: but in all its ſaline combinations, as well as in a free ſtate, it is readily deoxygenized, more or leſs perfectly, by heating with any carbonaceous matter. When it has thereby loſt its acid properties, it then acquires great volatility in fire,

[a] Bergman.

[b] Scheele.

and gives that peculiar odour which diſtinguiſhes heated arſenic or its oxyd. Thus, arſenic acid heated in a *platina ſpoon* by the blowpipe, ſimply melts into a glaſs, and gives neither fume nor ſmell; but heated *on charcoal* it is volatilized with a white denſe ſmoke and a ſtrong arſenical ſmell. Pelletier decompoſed it by hydrogen; for on paſſing this gas through a ſolution of arſenic acid in diſtilled water, it ſoon became turbid, and a black ſediment ſubſided, which proved to be arſenic in its reguline ſtate. Another complicated reduction, but in which hydrogen appears to be the real agent, is the following. If a piece of iron or zinc is thrown into liquid arſenic acid, and a little muriatic acid added, a great effervefcence of hydrogen enſues, and a precipitate of metallic arſenic is thrown down, mixed with arſeniat of zinc, which latter is ſeparable from the arſenic by cold muriatic acid. If the ſolution of the white oxyd of arſenic in water be put in ſimilar circumſtances, the precipitate is entirely metallic arſenic.[p] Scheele effected the ſame decompoſition by charcoal, for on mixing this acid with charcoal powder, putting them in a retort, driving off all the moiſture, and then luting on a receiver and increaſing the heat to redneſs, a ſhining regulus of very pure arſenic ſublimed into the neck of the retort, mixed with oxyd of arſenic, and a little charcoal duſt.

Pelletier alſo decompoſed it by phoſphorus. If a ſtick of phoſphorus is immerſed in liquid arſenic acid, in a few hours the phoſphorus blackens, and in time becomes covered by a very bright black metallic coating, which is reduced arſenic; whilſt the remaining liquor now contains phoſphoric acid.

Arſenic acid is reduced to the ſtate of white oxyd by digeſtion with its own regulus. This ſhews in a ſtriking manner the encreaſed degree of oxidation of the acid over the white oxyd.

* * *

Arſenic is little acted on by the alkalies or alkaline earths: but the white oxyd largely, and with eaſe. When ſaturated liquid potaſh is digeſted with this oxyd, aſſiſted by heat, a ſolution of the arſenic readily takes place, and gives a thick ropy tenacious fluid, of a ſtrong ungrateful ſmell, which on cooling becomes brittle and hard. This has been termed *Liver of arſenic*. It is uncryſtallizable, readily miſcible with water, and in the fire the oxyd moſtly flies off. Acids ſeparate the white oxyd, but do not precipitate the whole of the metal, for a ſmall portion always becomes converted in the proceſs into arſenic acid, which unites with part of the alkali as any other acid, and being largely ſoluble in water cannot be made to precipitate by any other acid, even by thoſe that have a ſtronger affinity for alkalies. The union of arſenic acid and the alkalies produces ſome of the moſt important *arſeniats*, to be preſently deſcribed. White arſenic is acted on by ſoda nearly as by potaſh. The carbonats of theſe two alkalies alſo diſſolve white arſenic very largely. This union of white arſenic and the fixed alkalies alſo takes place in the dry way by a melting heat, potaſh fixing twice, and ſoda three times its weight of white arſenic, according to Bergman.

Liquid ammonia forms a white concrete maſs with white arſenic, which when dry adheres to glaſs, but is ſoluble in water, and by ſlow evaporation gives ſmall cryſtals.[q] This ſolution is not decompoſable by acids, and the metallic oxyd appears to be brought nearly to the ſtate of perfect oxidation.

Lime and barytic-water diſſolve ſome white oxyd, which the acids again ſeparate. By fuſion, theſe earths unite with white arſenic into a glaſs, at firſt tranſparent, but ſoon becoming opake in the air. Strontian probably acts like barytes, but the other earths appear to have no ſpecific action on the oxyd, though they readily fuſe along with it, when aſſiſted by lime or barytes, into a clear glaſs, to which the oxyd proves a moſt powerful flux. All glaſſes holding a large portion of this metal are apt to become cloudy by expoſure to the atmoſphere.

Fat oils diſſolve arſenic, and more readily its oxyd, into a plaſtery maſs. Eſſential oils take up ſome of the oxyd.

Arseniats. The arſenic acid unites (like the other acids) with all the alkalies, and with ſome of the earths and metals. Theſe compounds are many of them highly intereſting.

If the acid of arſenic be ſaturated with potaſh, ſo as to leave however a ſlight exceſs of acid, a neutral ſalt is obtained, which cryſtallizes with great facility, and is the *arſeniat of potaſh*. It is procured with more eaſe by the diſtillation of white arſenic with nitre, a proceſs well known to the older chemiſts, but the exact theory of the operation was not underſtood till Scheele's diſcovery of the arſenic acid.

It is very accurately performed in the following manner. Mix equal parts of white arſenic and nitre, put them into a retort to which is

[p] Chenevix Ph. Tranſ. 1801. [q] Laſſone.

added a receiver, but not luted, or better, a Woulfe's apparatus. The retort ſhould be large, on account of the great ſwelling of the materials when they begin to act. Apply heat, and ſoon a large quantity of a very red incoercible nitrous vapour is given out, which on account of its very ſuffocating power ſhould be conducted up a chimney. If paſſed through water, a part is condenſed, but much of it paſſes through, and appears to be nitrous gas. From a mixture of ſixteen ounces of each of the materials (arſenic and nitre) Pelletier obtained 2739 cubic inches of this gas. When the nitrous acid and gas ceaſe to come over, and the retort is ſlightly red hot, the proceſs is compleated, and the reſidue, diſſolved to ſaturation in hot water, affords on cooling fine cryſtals of arſeniat of potaſh, mixed perhaps with a little undecompoſed nitre, from which it is eaſily diſtinguiſhed by the form, whiteneſs, and heavineſs of its cryſtals. A further evaporation and cooling afford more of this ſalt. Its uſual form is a four-ſided priſm, terminated by tetrahedral pyramids. The diſtillation of arſenic and nitre was long known to furniſh the abovementioned very fuming ſcarcely condenſible nitrous acid, but Macquer was the firſt who obtained the arſenical ſalt from the reſidue, and hence it is alſo called *Macquer's neutral arſenical ſalt*. A complicated apparatus is not at all neceſſary to procure it; if it be no object to the chemiſt to preſerve the nitrous acid that diſtills, a ſimple flaſk will anſwer every purpoſe. The acid then flies off, and the arſenical ſalt remains in the flaſk with the other reſidue. This ſalt may alſo be prepared in a crucible in the following way. [r] Melt nitre in a crucible made red hot only at the bottom, then throw in a little white arſenic on the point of a knife, which will cauſe much red vapour and efferveſcence. Repeat this addition by intervals, till the nitre begins to flow thick and paſty. When cold, diſſolve out the maſs with hot water, and by due evaporation arſeniat of potaſh will be obtained.

In all the above proceſſes the oxyd of arſenic firſt becomes fully oxydated by the acid of the nitre, and immediately unites with the alkali of this ſalt, while the acid, partly decompoſed and partly expelled by the metallic oxyd, flies off in red acid and nitrous gas. To cryſtallize readily, there ſhould not be an exceſs of alkali, for in this caſe the cryſtals will be ſmall and deliqueſcent. Therefore no more nitre ſhould be uſed than is requiſite to acidify the arſenical oxyd, nor ſhould it be too much or too long heated, for nitre loſes its acid ſimply by heat, and thus an exceſs of alkali is produced.

Arſeniat of potaſh is extremely fixed in the fire. It will bear long fuſion in a red heat without decompoſition. Mixed with about an eighth of charcoal powder, and heated in a cloſe veſſel, the whole of the arſenic riſes in the form of very fine ſublimed regulus, and the reſidue is a carbonated alkali mixed with part of the charcoal.

In eſtimating the affinities of arſenic acid to the fixed alkalies, compared with other acids, their degree of fixity in heat ſhould be taken into conſideration, for the arſenic acid is permanent at a very high temperature, and thus will take the place of a ſtronger acid with an alkali, when the latter acid is volatile or decompoſable by fire. Thus if one part of ſulphuric acid is added to two parts of arſeniat of potaſh, [s] and heated no further than to redneſs, the reſidue is a ſtrongly deliquſcent acid maſs, conſiſting chiefly of free arſenic acid and ſulphat of potaſh. But if the fire be urged further, the ſulphuric acid is again expelled, and diſtills over, partly as ſulphuric, partly as ſulphureous acid, whilſt the arſenic acid remains behind, and again unites with the alkali.

Arſeniat of Soda is formed as in the preceding caſe, either by the direct union of the arſenic acid with the alkali, or by the decompoſition of the alkaline nitrat, which in this caſe muſt be the nitrat of ſoda, or quadrangular nitre. The form of the cryſtalline ſalt is a hexagonal priſm truncated at the extremities. To cryſtallize eaſily, it is requiſite (according to Scheele) that there be a ſlight exceſs, not of acid as in the former caſe, but of alkali, for if more acid of arſenic be added to the ſolution, only a confuſed deliqueſcent maſs is obtained. If one part of common ſalt is diſtilled with three parts of acid of arſenic, [t] with a heat ſlowly encreaſed to redneſs, muriatic acid diſtills, and the reſidue is ſome common ſalt mixed with arſenic acid and ſoda, but with the acid in exceſs, and therefore uncryſtallizable till this exceſs is neutralized by the addition of chalk or alkali.

The volatile alkali ſaturated with arſenic acid gives on evaporation *arſeniat of ammonia*, which is not cryſtallizable, either when the ingredients are exactly ſaturated or when the acid is in exceſs. In the former caſe the form is a perfect rhomboid, [u] reſembling rhomboidal nitre and permanent; in the latter, the cryſtals are long, radiated, and deliqueſcent. Like the two former ſalts, this may be formed by diſtilling oxyd of

[r] Scheele. [s] Pelletier. [t] Scheele. [u] Pelletier.

arſenic with the alkaline nitrat, but here ſome peculiar circumſtances occur. Let white arſenic and nitrat of ammonia be mixed together, and put into a roomy retort with a large receiver. The fire muſt here be very moderate, otherwiſe the nitrat would ſpontaneouſly take fire and deflagrate, as it always does when heated ſtrongly, even without addition. The products are, fuming nitrous acid, then nitrat of ammonia and diſengaged ammonia, and if too much heat is uſed, ſome oxyd of arſenic ſublimes. The reſidue is arſeniat of ammonia, in the form of a vitreous maſs, but with ſuch an exceſs of acid as to corrode the glaſs of the retort juſt as pure arſénic acid does, and to make it crumble between the fingers. If carbonat of ammonia is added to ſaturation, a great effervescence takes place, and the ſolution now affords the perfect rhomboidal arſeniat of ammonia. This decompoſition of nitrated ammonia by oxyd of arſenic, may alſo be performed in a crucible heated ſlightly red, by projecting ſucceſſively ſmall portions of the mixture. But here the exceſs of arſénic acid acts on the clay of the crucible, as it did on the glaſs of the retort in the former inſtance, and it requires ſeveral filtrations and ſolutions to deprive it of this argillaceous impurity.

Arſeniat of ammonia does not retain its alkali when heated, as the two preceding ſalts do. When diſtilled it yields, firſt liquid ammonia, then white arſenic ſublimes, and at the ſame time much azotic gas is given out, and at laſt a white maſs remains quite fixed in the fire, which is pure arſénic acid; [v] and on encreaſing the heat it melts, ſtrongly corroding the glaſs. The production of the azotic gas, and the concomitant ſublimation of the white oxyd, are to be attributed to the decompoſition of part of the ammonia, its hydrogen reducing part of the perfect acid into the imperfect oxyd, whilſt its azot riſes in the form of a gas.

The combinations of the arſénic acid with the earths are little known, and comparatively of little importance.

Acid of arſenic dropped into lime-water forms an *arſeniat of lime*, which being ſcarcely more ſoluble than ſulphat of lime, ſinks to the bottom in the form of minute cryſtals. An exceſs of acid rediſſolves them. This ſalt is produced in the way of double affinity, by the addition of the nitrat, acetite, and ſome other ſalts of lime with the arſeniated alkalies.

Arſeniat of Magneſia is uncryſtallizable and little known.

The acid of arſenic acts with great energy on many of the metals forming *metallic arſeniats*, whoſe properties are curious and intereſting. Some of theſe, as the arſeniats of iron and copper, are found native. They will all be deſcribed under the reſpective metals, a few of their properties only will be mentioned here, as relating particularly to chemical analyſis. The metallic arſeniats may all be formed by double affinity, by adding liquid arſeniat of potaſh to the metallic ſulphats, nitrats, muriats, acetites, &c. The arſeniated metal thus produced is often a precipitate. Thus if arſeniat of potaſh is added to nitrat of ſilver, a brown-red arſeniat of ſilver is produced, and the ſolution contains nitrated potaſh, with ſome undecompoſed nitrated ſilver. The aqueous ſolution of the white oxyd of arſenic gives a dirty white precipitate. Nitrated iron gives a white precipitate with arſeniat of potaſh. With all the ſalts of lead a white precipitate of arſeniated lead is produced. This takes place even when arſénic acid alone is added to acetite of lead, but more ſlowly, the acid gradually ſaturating itſelf with the oxyd of lead before it precipitates. This arſeniat is alſo produced when acetite or nitrat of lead is added to arſeniat of copper, and it has been generally adopted in analyſis on account of the apparent uniformity of the compound, conſiſting of 33.2 per cent. of ſolid arſénic acid, ſo that 100 grains of this acid weigh 297 grains when ſaturated with lead. This arſeniat is inſoluble in water or alcohol, and hence when arſeniat of copper is decompoſed by nitrat or acetite of lead, the reſulting nitrat or acetite of copper may be readily ſeparated from the arſeniat of lead by alcohol. This arſeniat when heated by the blow-pipe *on charcoal* is reduced, the arſenic flies off in denſe garlic-ſmelling fumes, and a globule of pure lead is left behind: it is thus diſtinguiſhed from the ſulphat of lead. The arſeniat of ſilver is reduced in the ſame manner, and a globule of pure ſilver left behind.

A precipitate, formed by the addition of arſeniat of potaſh to ſulphat of copper, was firſt pointed out by Scheele, and is called after the inventor, *Scheele's Green.* (See COPPER.)

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The compounds of arſenic with *ſulphur* merit attention. Both the regulus and white oxyd unite readily with ſulphur, and the reſult is an amorphous maſs, of a fine yellow or red, according to the proportions, called in the former

[v] Scheele

caſe *yellow arſenic*, in the latter *ſandarac* or *realgar*. Similar combinations are alſo found native, and have been already mentioned. The exact proportions of each vary according to circumſtances, and it is not preciſely determined whether the colour is more owing to theſe proportions or to the degree of oxygenation of the arſenic. They are given however in the beſt authors [w] to be in the *red* ſulphuret 1 of ſulphur to 4 of arſenic, and in the *yellow* 1 to 9 or 10. Sulphur renders arſenic much more fixed in the fire, ſo that the red ſulphuret may be melted by moderate heat into a tranſparent maſs, called *arſenical ruby*. When the white oxyd or the arſeniates are uſed in the preparation, they oxygenate part of the ſulphur, and hence it gives out much ſulphureous acid gas. In the large way theſe ſulphurets are prepared as pigments, and the exact proceſs is not generally known, but it is ſaid to be by ſubliming in earthen veſſels iron pyrites mixed with miſpickel or ſome of the other native ores of arſenic and iron. The iron is certainly of great ſervice in diminiſhing the volatility both of the arſenic and the ſulphur, for a full red heat is requiſite to drive them off; and we find in the way of experiment, that a ſimple mixture of white arſenic and flowers of ſulphur ſublime too haſtily to contract a very cloſe union, and ſeldom produce an orpiment of a full uniform body of colour.

For experiment, the operation may be performed in a glaſs matraſs, ſlightly ſtopped at the mouth, and heated only at the bottom gradually to redneſs. Equal parts of white arſenic and ſulphur well mixed, yield in this manner a red ſublimate, which attaches itſelf to the neck of the veſſel. If two parts of arſeniat of potaſh and one of ſulphur, are ſlowly heated, barely red, for an hour in a matraſs, a very fine realgar or red ſulphuret ſublimes, and the reſidue at bottom conſiſts of yellow orpiment, mixed with *liver of arſenic*, or arſenic united with potaſh. The arſenic acid gives alſo a fine realgar. Six parts of liquid arſenic acid mixed with one of ſulphur, [x] give no ſigns of mutual action till the water is expelled, when on encreaſing the heat the whole riſes rapidly, and forms a fine red ſublimate of realgar, with a copious emiſſion of ſulphureous acid gas. The dry arſenic acid and ſulphur, in equal parts, heated for an hour, give the ſame products.

The yellow and red ſulphurets do not diſſolve in water. The nitro-muriatic acid by heat ſeparates the ſulphur from the arſenic, by diſſolving the latter: ſome of the ſulphur flies off as ſulphuretted hydrogen gas, whilſt the remainder falls to the bottom as a grey powder.

The fixed alkalies will ſeparate the ſulphur from the arſenic in the dry way, by diſſolving the former. For this, mix the arſenical ſulphuret with a little potaſh diſſolved in water, dry the mixture and ſlowly heat in a ſubliming veſſel. The arſenic riſes in the form of white oxyd, but only partially, much remaining behind united with the alkali, now ſulphuretted. If too much potaſh is uſed, no arſenic ſeparates, but the three ſubſtances remain united in fuſion. Cauſtic alkali diſſolves the arſenical ſulphuret in the moiſt way, for if they are boiled together, the reſult is an alkaline ſulphuret, holding arſenic in ſolution. An acid gives a bright yellow precipitate in this liquor, which is probably a hydroſulphuret of arſenic.

Quick-lime and orpiment boiled together produce a ſulphuret of lime, holding ſome arſenic in ſolution. This has long been known as infallible to cauſe the hair to fall off where it is rubbed, and is alſo uſed as a *wine-teſt* to detect the preſence of LEAD, which it does by making a black precipitate. By long keeping, this ſolution depoſits minute cryſtals of white arſenic.

The fat oils by heat diſſolve the arſenical ſulphurets into a very tough fetid maſs.

Sulphuretted alkalies alſo diſſolve the regulus of arſenic by fuſion, but the affinity is ſo weak as to be diſplaced by almoſt every other metal. A ſimilar ſolution takes place by boiling a watery ſolution of the alkaline ſulphuret with the regulus, and acids precipitate from this ſolution a red hydroſulphuret of arſenic. The ſame hydroſulphuret is produced in a ſimpler way by paſſing ſulphuretted hydrogen gas through a watery ſolution of white oxyd of arſenic, or by mixing the ſulphuretted water with the ſame.

Arſenic will unite with phoſphorus, and a *phoſphuret of arſenic* is produced in the following manner. Mix half a dram of white arſenic with a dram of phoſphorus, [y] and diſtill with a gentle heat in a cloſe veſſel. A red ſublimate is produced, and at the bottom remains a black brittle ſubſtance. The former appears, by the experiments of Pelletier, to be oxyd of phoſphorus, the latter is the phoſphuret of arſenic. It is obtained in greater abundance by diſtilling cautiouſly equal parts of regulus of arſenic with phoſphorus. The black ſhining reſidue is the phoſphuret of arſenic, and contains ſo much phoſphorus as to require to be kept under water. Both theſe preparations may be made in the moiſt way. Equal parts of regulus of arſenic

[w] Gren. [x] Scheele. [y] Margraaf.

and phoſphorus, heated with water to boiling, unite to a phoſphuret, the phoſphorus melting firſt and then acting on the arſenic. If equal parts of the white oxyd and phoſphorus are heated with water, the oxyd is decompoſed, and acidifies part of the phoſphorus (which diſſolves in the water), while the arſenic, now deoxygenated, unites with the phoſphorus, which remains unaltered.

For the union of arſenic with *hydrogen*, and the ſingular gas that reſults from this combination, ſee the next article.

The *alloys* of arſenic are very numerous. Arſenic added to the metals when in fuſion unites with moſt of them, and forms an alloy, which is always brittle in proportion to the arſenic contained, and generally much more fuſible than the metal with which it is thus united. It alſo often alters the colour of the metal, rendering the yellow metals white, and the white, grey. Theſe alloys are moſtly hard as well as brittle, and on expoſure to air are apt to aſſume a leaden black colour. The arſenic is generally ſeparable from theſe alloys by ſimply heating them for ſome time to redneſs, and it flies off in its diſtinguiſhing garlick-ſmelling white fumes. If this proceſs is carried on too haſtily, ſome of the other metal is volatilized. Even gold alloyed with arſenic is thus diſſipated by roaſting. Platina alone appears abſolutely fixed in theſe circumſtances, and it even retains a portion of arſenic ſo obſtinately that mere heat cannot drive it off.

Even the white oxyd of arſenic, heated with the metals, becomes in part reduced to the reguline ſtate, and unites with part of the metal, whilſt the other part becomes oxygenated, doubtleſs by taking oxygen from the arſenical oxyd, and appears on the ſurface of the alloy as a coloured ſcoria.

The great volatility of arſenic, either reguline or oxidated, when heated, renders it difficult to unite it by fuſion with the metals that cannot themſelves be melted with leſs than a red heat. There are two or three ways however of managing this combination. One is by firſt bringing the metal into fuſion, then throwing in the crucible the arſenic, haſtily mixing them, and cooling the alloy ſpeedily, before much of the arſenic has had time to evaporate. Some artiſts in this way unite arſenic and copper, by melting the copper, wrapping up the arſenic in paper, and thruſting it with hot pincers to the bottom of the melted metal, through which it immediately riſes and diffuſes itſelf pretty uniformly. Another method is to mix the white oxyd of arſenic with charcoal, and put it at the bottom of a tall crucible, over this to ſpread a layer of clay, and above the clay to ſtrew the filings of the metal, with which the arſenic is to be alloyed. By heating the crucible, the arſenical oxyd becomes reduced by the charcoal, ſublimes in the metallic ſtate through the clay, and unites with the heated metal above, fuſing it down, in proportion as the alloy becomes ſaturated with arſenic. A third method, and the moſt convenient, is to employ the white oxyd of arſenic, and to mix it with an alkali (with or without a carbonaceous flux) and heat it with the metal. Soap is a very good addition in this caſe, as it furniſhes the arſenical oxyd with both carbon from its oil, and with alkali. The latter keeps down the arſenic and renders it much more fixed in the fire, as has been before mentioned in deſcribing the combination of theſe two ſubſtances. When no carbonaceous matter is preſent, the arſenical oxyd becomes reduced at the expence of part of the other metal, which therefore is found partly oxidated, and ſeparates from the alloy uniting with the alkali into a ſcoria.

Thoſe of the arſenical alloys which are uſed in the arts, ſuch as *White* COPPER, the LEAD alloy for ſhot, arſenicated PLATINA, &c. will be mentioned under theſe metals; the following are more curious than uſeful, and ſerve to illuſtrate the foregoing obſervations. The experiments are thoſe of Achard. [z]

An ounce of tin, with as much white oxyd of arſenic, diſtilled in an earthen retort for half an hour to redneſs, gave ſome ſublimed arſenical oxyd, and in the retort remained an alloy covered with a white ſcoria, and weighing $\frac{1}{2}$ an ounce and 3 drams. This retained part of its ductility, but was eaſily broken, and exhibited in its fracture large brilliant flat blades. It was tin combined with a little arſenic. Six parts of tin melted with one of white arſenic, and nine of carbonat of potaſh, gave an alloy, whoſe fracture ſhewed very brilliant rhomboidal facets well cryſtallized. Remelted without addition, it reſembled zinc in its fracture, and acquired nearly the ſame degree of ductility as that metal. Equal parts of *oxyd* of tin and white arſenic, heated together in a retort, gave a very mixed ſublimate, containing alſo ſome regulus of arſenic, but the tin was not quite reduced to the metallic ſtate.

Caſt *iron*, white arſenic, and carbonat of potaſh melted together, gave an extremely brittle cloſe-grained alloy of arſenic and iron. Iron

[z] Mem. de l'Acad. de Berlin, 1781.

filings diſtilled with white arſenic gave a black unmetallic maſs, but ſtill attracted by the magnet. Iron ſaturated, or nearly ſo, with arſenic is not magnetical.

Lead fuſed with white arſenic and alkali, gave an alloy reſembling that of tin in the ſame circumſtances, but by a ſecond fuſion almoſt all the arſenic was expelled, ſo weak is the affinity between theſe metals in their reguline ſtate.

As the arſenic uſed in all theſe experiments was employed in the ſtate of white oxyd, unaccompanied by any reducing flux, and yet, as in all, a greater or leſs reduction of it to the metallic ſtate took place (the alloy being neceſſarily in the metallic ſtate) this reduction was obviouſly owing to the oxidation of a portion of that metal, whilſt the reguline arſenic combined with the remainder.

Arſenic is one of the leaſt valuable of the metallic ſubſtances. Its violent effects on the animal body when taken internally, and the eaſy ſolubility of its oxyds in almoſt every fluid, render it always ſuſpicious, and often highly dangerous, when employed in the arts. The white oxyd is however largely employed as a cheap flux for glaſſes of different kinds, and it acts in this way in a very powerful manner; but if too much is employed, veſſels made of it are not abſolutely ſafe for domeſtic purpoſes, and are apt to become opake. The red and yellow ſulphurets afford good pigments to the painter.

The moſt deciſive experiments for the detection of arſenic, when ſuſpected to be contained in any ſubſtance, are the following. Boiled in water, even the white oxyd (the preparation the moſt likely to occur) makes a ſolution of ſufficient ſtrength to give very clear indications of its nature. 1ſt. Sulphuretted hydrogen paſſed through the ſolution, or water ſaturated with the gas, added to it gives a golden yellow precipitate. 2d. An extremely ſmall quantity of carbonat of potaſh added to the ſolution, and then mixed with a ſolution of ſulphat of copper, gives a yelloviſh green precipitate. 3d. The dried ſubſtance to be examined, or the ſolution evaporated to dryneſs, mixed with a little powdered charcoal, and put into a glaſs tube cloſed at the bottom, lightly ſtopped at the top, and heated ſlowly to redneſs, will yield a metallic ſublimate, which will give the ſtrong ſmell peculiar to arſenic, and will condenſe on the ſides of the tube, lining it with a brilliant metallic coating. 4th. The ſame ſtrong ſmell, and a denſe white fume will be given, merely by ſprinkling the powder on hot charcoal. 5th. A little of the reduced regulus, or of the ſuſpected powder, *mixed with a little charcoal*, laid between two pieces of copper (halfpence for example) ſcoured quite bright, bound round with wire, and heated red-hot for a few minutes, will leave on each piece of copper a bright white ſtain, which cannot be rubbed off, except by making a new ſurface. All theſe marks combined, cannot fail to indicate the preſence of arſenic.

The affinities of the arſénic are the following. *In the moiſt way*, lime, barytes, ſtrontian, magneſia, potaſh, ſoda, ammonia, alumine, and metallic oxyds. *In the dry way*, lime, barytes, ſtrontian, magneſia, potaſh, ſoda, metallic oxyds, ammonia, and alumine.

The affinities of oxyd of arſenic are, *in the moiſt way*, muriatic, oxalic, ſulphuric, nitric, ſebacic, tartareous, phoſphoric, ſuccinic, citric, formic, arſénic, acetous and pruſſic acids, ammonia, fat oil and water. *In the dry way* the affinities of the regulus of arſenic are nickel, cobalt, copper, iron, ſilver, tin, lead, gold, platina, zinc, antimony, alkaline ſulphuret, and ſulphur.

ARSENICAL NEUTRAL SALT *(of Macquer)* is the cryſtallized arſeniat of potaſh, firſt diſcovered by this eminent chemiſt. *(See the preceding article.)*

ARSENICATED HYDROGEN GAS.

This ſingular gas was firſt diſcovered by Scheele,[a] who on digeſting zinc with arſénic acid, obſerved an effervеſcence, and the evolution of a gas with a diſagreeable arſenical ſmell, which would not unite with water, would not diminiſh the bulk of common air mixed with it, and when thus mixed detonated violently on applying a candle, and left on the ſides of the veſſel a ſhining pellicle of reguline arſenic. Hence he concluded juſtly that it conſiſted of inflammable air, holding arſenic in ſolution. This gas has more lately been examined by Trommſdorf,[b] who has aſcertained many other of its properties.

There are ſeveral methods of preparing this gas. Tin, zinc, or iron filings, digeſted in arſénic acid, will yield it, and during the proceſs, arſenic alloyed with the other metal is precipitated. White arſenic, dilute ſulphuric acid, and iron or zinc will equally yield it; in ſhort it appears to be given out whenever arſenic either reguline, or an oxyd, or an acid is preſent, under circumſtances which cauſe the evolution of hydrogen gas. In all theſe inſtances the

[a] Eſſays. [b] Mem. Acad. Berlin, or Phil Jour. vol. 6.

arſenic diſſolved in the gas is in the metallic ſtate, hydrogen having always a ſtrong tendency to reduce this as moſt other metallic oxyds. —The preciſe proportions recommended by Trommſdorf, are four parts of granulated zinc, one of white arſenic, with ſulphuric acid diluted with twice its weight of water. The reſidue, after the production of the gas, contains metallic arſenic.

Arſenicated hydrogen is a true chemical compound of arſenic and hydrogen. It has moſt of the properties of hydrogen, and ſuperadded, thoſe which would naturally be expected from the preſence of a metal ſo combuſtible and eaſily acidifiable as arſenic. The ſmell is ſtrongly arſenical, and beſides being fatal when reſpired unmixed, it appears extremely noxious to perſons much expoſed to it in a room, ſo that experiments on it are not made without much temporary inconvenience.

Water does not abſorb it, nor is litmus tincture altered by it. Its ſpecific gravity, at 29.8 inches (Engliſh) barom. is 0.5293 (water being 1000), ſo that a cubic foot (Engliſh) will weigh nearly 285 troy grains, or .1649 grains the cubic inch. It is therefore heavier than ſulphuretted hydrogen, and much heavier than pure hydrogen, but lighter than ammonia and all the other gaſſes.

The action of the oxygenized muriatic acid on this gas is very ſtriking. When the acid, in form of gas, is paſſed up through a veſſel of arſenicated hydrogen, the bulk is leſſened, heat is given out, and arſenic is depoſited on the ſides of the veſſel. An additional quantity produces white fumes (probably ſimilar to thoſe of butter of arſenic) and the metal is rediſſolved. By exact ſaturation, nearly the whole of the arſenic can thus be precipitated, and the identity of this metal can then be proved by all the experiments which the known properties of arſenic, deſcribed in the foregoing article, would ſuggeſt. When this experiment is performed over mercury, a precipitation of water is apparent. Simple muriatic gas produces no change, and hence it appears that the action of the firſt portion of oxymuriatic acid is to produce water by union of its oxygen with the hydrogen of the arſenicated gas, and thus to precipitate the arſenic in a metallic ſtate; after which, however, the acid gas no longer acts upon the hydrogen, this having depoſited all its arſenic, but upon the arſenic itſelf, and proceeds to form the muriated oxyd, and probably the arſenic acid. In confirmation of this, the author of the above experiments, by reverſing the proceſs (that is by paſſing the arſenicated hydrogen into the oxygenized muriatic acid gas) obſerved at firſt the production of the white fumes only, and it was not till the former gas had been added to ſaturation that metallic arſenic was precipitated. Liquid oxymuriatic acid decompoſes arſenicated hydrogen by mere agitation, and the reſult is pure hydrogen. The nitro-muriatic acid acts in the ſame manner, but during the mixture a black precipitate is obſerved (doubtleſs arſenic), which directly afterwards diſappears.

If a ſmall quantity of fuming nitrous acid is thrown into a phial full of the gas, it becomes immediately filled with denſe red fumes, and a white flame ariſes, and a detonation enſues. With dilute nitric acid no ſuch appearance is obſerved. The reſidue is pure hydrogen, and the water contains arſenic acid.

Concentrated ſulphuric acid added to the gas produces an immediate precipitation of metallic arſenic, which lines the glaſs veſſel, and makes it a perfect mirror, but on agitation, the metallic coating is turned into a brown powder, which in a few days changes to red.

Sulphuretted hydrogen and arſenicated hydrogen, ſimply mixed, do not act upon each other, but when oxygenized muriatic gas is added, the bulk diminiſhes, heat is given out, and orpiment precipitates, which by encreaſing the doſe of the acid gas becomes of a fine orange red. This beautiful experiment will ſerve as a teſt of arſenicated hydrogen even when much diluted.

If a lighted taper is let down into a phial of this gas, it is extinguiſhed, but the gas kindles at the ſurface, giving a blue lambent flame and a ſtrong arſenical fume. As the flame proceeds gradually downwards (provided the veſſel has a ſmall orifice) the arſenic is depoſited on the ſides, whilſt the hydrogen ſlowly conſumes. Mixed with oxygen and kindled, the gas burns with a loud exploſion, and here no arſenic is depoſited, but the products are arſenic acid and water. If a ſtream of the arſenical gas is kindled and made to paſs through a large veſſel of oxygen, the flame is very brilliant.

When this gas is paſſed through metallic ſolutions, it decompoſes many of them, and cauſes a precipitate of the two metals.

If the compoſition of this gas is ſimply arſenic diſſolved in hydrogen gas, and if after the ſolution the hydrogen retains the ſame bulk which it would have when pure, the compoſition would be ſimply the following:

	grain
One cubic inch of arſenicated hydrogen weighs	.1649
of pure hydrogen - - - - -	.0239
difference	.141

ſo that every cubic inch of the arſenicated gas would hold in ſolution .141, or ſomewhat leſs than one-ſeventh of a grain of arſenic.

ASBEST. *Talcum aſbeſtus*, Werner. *Aſbeſte*, Hauy and Brochant. *Aſbeſt*, Emmerling.

Aſbeſt is of a texture more or leſs filamentous, and by trituration is reducible to a ſoft ſomewhat fibrous powder. It is commonly divided into four varieties.

I. Amianth, or Mountain Flax. *Biegsamer aſbeſt*, Emmerling. *Aſbeſte flexible*, Hauy.

The uſual colour of this mineral is greeniſh white, paſſing into leek-green; or ſilver white, yellowiſh-white, ochre-yellow, pale fleſh red, and, very rarely, light blue. It is found ſometimes in ſmall ſeparate bundles, but more uſually in irregular fibrous maſſes. Its luſtre is glimmering or ſlightly ſhining, and is either weak, pearly or ſilky. It is eaſily diviſible into long ſlender flexible fibres, may be ſcratched by the nail, and has a ſoft ſomewhat greaſy feel. It is generally opaque, but ſometimes is tranſlucid on the edges. Its ſpecific gravity is ſubject to great variety; that of the moſt flexible and perfectly fibrous is only 0.908; that of the moſt compact is 2.313.

According to a late analyſis of this mineral by Chenevix it appears to contain

25.	magneſia,
59.	ſilex,
3.	alumine,
9.25	lime,
2.25	oxyd of iron.
98.5	
1.5	loſs
100.	

Before the blowpipe amianthus melts with ſome difficulty into an opaque globule, which becomes dark-coloured by the continued action of the flame. If expoſed to a high heat in an earthen crucible, it melts into a denſe ſlag, ſtrongly adhering to the veſſel, of a yellowiſh grey colour: the ſurface of this ſlag is overſpread with cryſtalline needles, croſſing each other in all directions, or radiating from a common centre. If the heat is conſiderably increaſed, the whole melts into a green glaſs, and in a ſhort time paſſes through the crucible. A ſpecimen of amianthus, from Greenland, being incloſed by Klaproth[a] in a charcoal crucible, and expoſed to the full heat of a porcelain furnace, fuſed into a finely porous maſs, of a dirty pearl-grey colour, covered externally with grains of iron.

This mineral is met with in potſtone or ſerpentine rocks, either diſperſed through them or accumulated in their clefts and crevices, unmixed with any other ſubſtance. The moſt beautiful comes from the Tarentaiſe, in Savoy; it is in white-flexible filaments, ſometimes a foot long, of a pure ſilky luſtre. In ſome parts of Corſica it is ſo common as to have been uſed by Dolomieu inſtead of hay or moſs, to pack up ſpecimens of other minerals in. The iſlands of Elba and Crete; Zoblitz, in Saxony; Suartwick, in Sweden; Cornwall and Angleſey, in England; and Portſoy, in Scotland, alſo furniſh conſiderable quantities. A compact kind, which decompoſes by expoſure to the air into remarkably flexible threads, is found in the Oural Mountains in Siberia.

The fibrous texture of amianthus, its incombuſtibility, and the little alteration that it undergoes even in a ſtrong heat, were early noticed, eſpecially among the Eaſtern nations; and methods were found out of drawing the fibres into thread, and afterwards weaving it into cloth. This, when dirtied with greaſe, or other inflammable matter, was cleaned by throwing into a bright fire; the ſtains were burnt out, and the cloth was then removed, but little altered in its properties, and of a dazzling white, hence it obtained from the Greeks the name *αμιαντος* or *undefiled*. In the rich and luxurious times of the Roman empire, this incombuſtible cloth was purchaſed at an enormous price, for the purpoſe of wrapping up the bodies of the dead previouſly to their being laid on the funeral pile. The practice of burning the dead falling into diſuſe, occaſioned the manufacture of amianthine cloth to be neglected, and at length entirely forgotten in Europe; but though it has ceaſed to be an article of neceſſity or luxury, yet the method of its preparation has occaſionally attracted the notice of travellers and occupied the time of the curious. Ciampini,[b] of Rome, in 1691, publiſhed the following as the beſt way of preparing the in-

[a] Analyt. Eſſ. vol. 1.

[b] De incombuſtibili lino.

combuſtible cloth. Having previouſly ſteeped the amianthus in warm water, divide its fibres by gently rubbing them with the fingers, ſo as to looſen and ſeparate all the extraneous matter; then pour on repeatedly very hot water, as long as it continues to be in the leaſt diſcoloured. Nothing will be now left but the long fibres, which are to be carefully dried in the ſun. The bundles of thread are to be carded with very fine cards, and the long filaments thus obtained are to be ſteeped in oil, to render them more flexible. A ſmall quantity of cotton or wool is to be mixed, and by means of a thin ſpindle the whole is to be drawn out into thread, taking care that in every part the amianthus may be the principal material. The cloth being then woven in the uſual manner, is to be placed in a clear charcoal fire to burn off the cotton and oil, when the whole remaining tiſſue will be pure white amianthus. The ſhorter fibres that are incapable of being woven, have been ſometimes made into paper, the proceſs for which is the ſame as that employed for common paper, except that a greater proportion of paſte or ſize is required: after having been made red hot, however, this paper becomes bibulous and brittle. Amianthus threads are alſo ſometimes uſed as perpetual wicks for lamps; they require, however, to be cleaned occaſionally from the ſoot that collects about them, and the fibres in the hotteſt part of the flame are apt to run together, ſo as to prevent the due ſupply of oil. In Corſica,[c] amianthus is advantageouſly employed in the manufacture of pottery: being reduced to fine filaments, it is kneaded up with the clay, and the veſſels which are made of this mixture are lighter, leſs brittle, and more capable of bearing ſudden alterations of heat and cold than common pottery.

II. Common Aſbeſt. *Gemeiner aſbeſt. Aſbeſte dure*, Hauy.

The colour of this mineral is leek, or mountain, or olive-green; greeniſh or yellowiſh-grey, or greyiſh-white. It is found amorphous, or inveſting other ſubſtances; the form of its filaments appears to be that of a very long rhomboidal priſm: it is ſhining or glimmering, with ſomewhat of a greaſy luſtre: its fracture is fibrous, and much more compact than that of the amianthus, paſſing into the broad-ſtriated. It flies when broken into long ſplintery fragments: it is tranſlucid at the edges, and may be ſcratched by the nail with ſome difficulty. Sp. gr. 2.5. to 2.8.

The component parts of common aſbeſt, according to Wiegleb, are

48.45	magneſia,
46.66	ſilex,
4.79	oxyd of iron.
99.90	

Aſbeſt is of more frequent occurrence than amianthus, being found almoſt univerſally accompanying ſerpentine, and very often mixed with magnetic iron ore. It paſſes by inſenſible gradations into the preceding ſpecies.

III. Ligniform Aſbeſt. *Holzaſbeſt. Aſbeſte ligniforme*, Hauy.

The colour of this mineral is yellow or iſabella brown. It is found maſſive, and is internally glimmering. Its fracture is thin and finely foliated: it is opaque, may be ſcratched by the nail, adheres to the tongue, has a meagre feel. Sp. gr. 2.051.

It is not fuſible *per ſe* before the blowpipe.

It is met with principally in the Schneeberge of Tyrol, in the ſame gangue with galena, blende, common aſbeſt, ſtrahlſtein, and gypſum.

IV. Mountain Cork. Mountain Leather. *Schwimmender Aſbeſt. Aſbeſt treſſe*, Hauy.

The colour of this mineral is yellowiſh or reddiſh white, yellowiſh green or ochre yellow. It is found amorphous in thick or thin plates: it is weakly glimmering, internally. It has a thick, uneven, ſomewhat foliated fracture; is opaque, ſomewhat elaſtic, and floats upon water. Sp. gr. 0.68 to 0.99.

It conſiſts, according to Bergman, of

26.10	magneſia,
56.2	ſilex,
2.	alumine,
12.7	lime,
3.	oxyd of iron.

In a ſtrong heat it flows with difficulty into an opaque milk-white glaſs.

It is found in the ſame ſituations as amianthus.

ASBESTINITE. See STRAHLSTEIN.

ASBESTOID. See STRAHLSTEIN.

ASHES. *Aſche*, Germ. *Cendres*, Fr.

The pulverulent reſidue of combuſtible bodies after burning is in general denominated aſhes; the produce of the combuſtion of metals however is no longer known by the name of *metallic aſhes* but of calx or OXYD. We ſhall therefore in the preſent article confine ourſelves to the aſhes from vegetable and animal ſubſtances.

[c] Hauy Mineralog. vol. iii. p. 252.

When a *vegetable* is subjected to deſtructive diſtillation, all the native juices are more or leſs altered and decompoſed, and fly off in the ſtates of gas and vapour; what remains behind is a light, brittle black maſs, ſtill exhibiting very perfectly the texture of the plant, and incapable of alteration by any further degree of heat in cloſe veſſels. By the joint action of heat and air, however, the texture is deſtroyed, the carbonaceous matter is converted to carbonic acid gas, and a white or reddiſh yellow uninflammable powder remains behind, which is the aſh or aſhes. The aſhes conſiſt principally of earths and earthy ſalts, but contain beſides alkaline and neutral ſalts and metallic oxyds. The earths and earthy ſalts are ſilex, the carbonats of magneſia and lime, the ſulphats and muriats of the ſame, and phoſphat of lime. The alkaline and neutral ſalts are the carbonats of potaſh and ſoda, together with the ſulphats and muriats of the ſame. The metallic ſubſtances are the oxyds of iron and manganeſe. The quantity of aſhes is by no means proportionate to the ſolidity of the vegetable, ſome very compact and hard woods yielding leſs of this ingredient than certain ſucculent plants. By ſimple lixiviation the ſaline ſubſtances may be ſeparated from the earthy and metallic parts; and this being the method in which the potaſh and ſoda of commerce are prepared, the analyſis of vegetable aſhes is a matter of no ſmall importance: the French chemiſts in particular have beſtowed much attention on the ſubject, and the reſults of their enquiries the reader will find detailed hereafter in the articles CARBONAT *of Potaſh* and CARBONAT *of Soda*..

The volatile parts of *animal* matter may be driven off with nearly the ſame eaſe as thoſe of vegetables, and the reſult of each proceſs is a ſpungy coal. Animal coal however is of a much greater ſpecific gravity than that from vegetables, and requires a long and intenſe heat for its incineration; the aſhes are alſo more copious in proportion, and conſiſt for the moſt part of carbonats and phoſphats of lime and ſoda. For other particulars relative to animal aſhes the reader is deſired to refer to the articles BLOOD, BONE, HORN, SHELL.

ASPHALT. See BITUMEN.

ASSAY or *Eſſay*. *Eſſai*, F. *Probiren*, G.

The term ASSAY, in chemiſtry, in a general ſenſe, implies the analyſis or examination of a ſample of any ſubſtance, whoſe chemical compoſition is to be aſcertained; but this term is alſo technically reſtricted to the analyſis of gold and ſilver mixtures, with the expreſs and ſole purpoſe of determining the proportion of noble metal to that with which it is alloyed, in any individual maſs. It is only in this ſenſe that we here underſtand it, and on account of the vaſt quantity of coin, plate, and plate ornaments which are conſtantly fabricated, the buſineſs of the aſſayer becomes of extreme importance; for few operations in chemiſtry require ſo nice and minute attention, and ſuch practical experience as one, which, from the ſample of a few grains, is to decide the ſtandard of very large maſſes of the moſt valuable metals.

Gold and ſilver aſſaying is, however, in principle extremely ſimple, the whole being included in two operations, namely, the ſeparation of the alloy from the noble metals, and the parting of theſe latter (gold and ſilver) from each other. Theſe proceſſes muſt be conſidered ſeparately.

Of all the metals hitherto known, three alone, gold, ſilver, and platina, are incapable of oxidation by ſimple expoſure to air, either when ſolid or in a ſtate of fuſion, and hence they acquired the antient name of *perfect* or *noble* metals. All the other metallic bodies tarniſh and oxidate, when in fuſion in open veſſels, with more or leſs facility, and by conſtantly removing the oxidated ſurface from the melted metal, the whole may be ſucceſſively converted to an oxyd. Here, therefore, is a method of ſeparating the imperfect from the perfect metals, when the two ſpecies are mixed; namely, to melt the mixture and keep it in fuſion with acceſs of air, when the *alloy*, or imperfect metal will ſeparate at the ſurface in oxidated ſcales, and the noble metal remain unaltered. This ſeparation, however, is not in all caſes equally exact, for when gold or ſilver is alloyed with a metal not very eaſily oxidable, though imperfect, ſuch as copper, and when the proportion of the alloy to the noble metal is but ſmall, the affinity of the latter to the former encreaſes ſo much as to protect it from any further action of the air, however long the fuſion is kept up. Thus a maſs of eleven parts of ſilver to one of copper, oxidates but lightly by a long continued melting heat, nor could the whole of the copper be extracted from the mixture by heat alone. Another difficulty in the way of this ſeparation is the very difficult fuſibility of the oxyd of copper (for all metallic oxyds by heat melt into a ſpecies of coloured glaſs), ſo that in a heat much above that at which the mixture remains in fuſion, the cruſt of oxyd clings unmelted to the ſurface of the fluid metal, and unleſs aſſiduouſly removed, it there remains, and prevents the further action of the air on the alloy, by

which alone all the imperfect metal can be thrown off from the mafs.

But chemifts have found that the feparation of many of the imperfect metals is much promoted by adding to the mixture a quantity of a metal, itfelf highly oxidable, and its oxyd eafily fufible, which unites with the original alloy of the mixture, encreafes its oxidability, carries it off diffolved in the vitrified oxyd, and thus compleatly extracts from the mafs all the imperfect metal or alloy, leaving the noble metal or metals pure.

A few of the more fufible white metals have been tried for this purpofe, particularly lead and bifmuth; but lead is found to anfwer the end better than any other, and is the only fubftance actually ufed. Hence litharge, the oxyd of lead, was termed by the antient chemifts, not unaptly, *the bath* of the noble metals, *fcouring* or *cleanfing* them, as it were, from all their alloys of bafe metal, and leaving them quite bright and pure.

This procefs of oxidation of the alloy by lead is employed in the large way in the *refining* of gold and filver; in fmall famples, with the peculiar precautions to be prefently mentioned, it forms the procefs of *cupellation*, which, therefore is the firft and moft important part of the aflayers bufinefs.

The fecond procefs is the feparation of the gold from the filver, where both metals are prefent, for being equally perfect, or unoxidable by mere fufion, they are left uniformly mixed by melting, after the alloy has been feparated by cupellation. The method of feparating gold from filver is by the nitric acid, which if properly managed, may be made to diffolve all the filver and leave all the gold. This procefs is called *Parting*, and is the fecond great operation of the aflayer. Platina may in general be put out of the queftion, and it feldom is contained in any gold or filver alloy actually ufed, but when prefent it occafions fome peculiar appearances, which will be afterwards noticed.

Cupellation. This procefs is performed in a furnace contrived for the purpofe, and capable of giving a heat at leaft fufficient for the eafy fufion of gold. *(Its conftruction is explained in the Appendix.)* In the middle of this furnace is placed an earthen pot called a *muffle*, of an oven form, vaulted at top, with a level floor at bottom, entirely open at one end, and clofed every where elfe, except a few narrow flits through the fides. The open end comes in contact with a door at the fide of the furnace, and is generally luted thereto, fo as entirely to feparate it from the burning fuel. The body of the muffle is furrounded with the coals, and before cupellation is gradually heated to a glowing rednefs. Its ufe is to protect the fmall crucibles or cupels, ranged on its floor, from any accidental impurity which the fuel might furnifh, and at the fame time to afford the melted metal a free acceis of heated air to promote the oxidation. The cupels are folid pieces of earth, cubical or circular, with a fhallow depreffion at the top to contain the metal, and fmall in proportion to the fize of the muffle, fo that the floor of this latter will hold feveral of them fide by fide. They are made folid, but at the fame time fo porous as freely to abforb the lead, in proportion as it oxidates and vitrifies, whilft the globule of metal that remains in the reguline ftate refts on the furface. Cupels may be made of any infufible earth of little cohefion, fuch as the afhes left after the lixivation of the refidue of burnt wood, which are much employed in refining, or cupellation in the great way, but for aflaying they are made entirely of bone-afh (phofphat of lime) ground to a fine powder, moiftened with water, fo as to take the impreffion of a mould, and afterwards thoroughly dried. The cores of ox-horns are preferred at the Tower Aflay-Office.

The fire being kindled, the muffle and empty cupels are firft heated gradually, till the whole are of a glowing red, a little powdered chalk or fand being firft fprinkled on the floor of the muffle, to prevent the adhefion of the cupels by the litharge foaking through them. They are then ready to receive the metal to be cupelled. It fhould be obferved that the cupels of bone-afh cannot abforb more than their own weight of litharge at the utmoft, and hence the quantity of fine metal to be aflayed fhould not require more lead than the weight of the cupel. The proportion of lead to the fine metal is determined by the eftimated purity of the latter, as will prefently be mentioned.

Experience has fhewn the extreme difficulty of conducting cupellation at all times with perfect accuracy, even to perfons habitually employed in this delicate operation, and many valuable feries of experiments on this fubject have been undertaken by able aflayers, among which we may particularly mention thofe of M. Tillet, and his aflociates, nominated by the French government, and publifhed in the memoirs of the academy in the years 1763—9—75—6—8—80—8.

Aſſay of Silver.

For the aſſay of ſilver, in this country, a clean piece of the metal is firſt taken, not more than 36 grains, and leſs if the alloy appears to be conſiderable, is laminated, and weighed with extreme accuracy in a very ſenſible balance. It is then wrapped up in the requiſite quantity of lead, revived from litharge, and for convenience rolled out into a ſheet; or elſe the ſilver and lead may be together cloſed in paper. The purity of the lead is of importance, as all lead only once reduced from its ore contains ſome ſilver, the quantity of which might make ſome notable error in the delicate operations of the aſſayer. But when revived from litharge lead retains no more than about half a grain of ſilver to the pound, which may be entirely neglected.

When the muffle and cupel are fully red hot, the ſilver and lead are then put in the cupel with a pair of pincers, when they immediately melt; and when red the following appearances take place. The melted metal begins to ſend off denſe fumes, and a minute ſtream of red fuſed matter is ſeen perpetually flowing from the top of the globule down its ſides to the ſurface of the cupel, through which it ſinks in and is loſt to view. This fume and the ſtream of melted matter conſiſt of the lead oxidated by the heat and air, in one caſe volatilized, in the other vitrified, and in ſinking through the cupel it carries down with it the copper or other alloy of the ſilver. In proportion to the violence of the heat is the denſity of the fume, the violence with which it is given off, the convexity of the ſurface of the globule of melted metal, and the rapidity with which the vitrified oxyd *circulates* (as it is termed) or falls down the ſides of the metal. As the cupellation advances, the melted button becomes rounder, its ſurface becomes ſtreaky with large bright points of the fuſed oxyd, which move with increaſed rapidity, till at laſt the globule being now freed from all the lead and other alloy, ſuddenly *lightens*; the laſt portions of litharge on the ſurface diſappear with great rapidity, ſhewing the melted metal bright with irideſcent colours, which directly after becomes opake, and ſuddenly appears brilliant, clean, and white, as if a curtain had been withdrawn from it. The operation being now finiſhed, and the ſilver left pure, the cupel is allowed to cool gradually, till the globule of ſilver is fixed, after which it is taken out of the cupel while ſtill hot, and when cold weighed with as much accuracy as at firſt. The difference between the globule and the ſilver at firſt put in, ſhews the quantity of alloy, the globule being now perfectly pure ſilver, if the operation has been well performed. The reaſon of cooling the globule or button gradually is, that pure ſilver, when congealing, aſſumes a cryſtalline texture, and if the outer ſurface is too ſuddenly fixed, it forcibly contracts on the ſtill fluid part in the center, cauſing it to ſpurt out in arboreſcent ſhoots, by which ſome minute portions are often thrown out of the cupel and the aſſay ſpoilt.

In the delicate aſſays for the Mint, in the Tower of London, two aſſays are always made of the ſame maſs of metal, and no ſenſible difference between the weight of the two buttons is allowed to paſs, aſcertained in ſcales which turn with $\frac{1}{1200}$ of a grain troy. If they differ the aſſay is repeated.

The proceſs is conſidered as well performed when the button of ſilver adheres but ſlightly to the cupel; when its ſhape is very conſiderably globular above and below, not flattened at the margin; when it is quite clean and brilliant, ſhewing the beautiful white of pure ſilver, and not in any degree fouled or ſpotted with any remaining litharge; and eſpecially when the ſurface of the metal is diſpoſed in ſcales or laminæ, the effect of a ſtrong but haſty cryſtallization, which gives it a play of light and a ſtriated luſtre very different from that of a perfectly even ſurface of a white metal, however pure. Examined by a microſcope, this ſtriated ſurface is ſtill more ſtriking;[a] the ſcales appear to affect the form of an irregular pentagon, ſlightly depreſſed at the centre, and the ſurface is decidedly uneven. On the other hand, when any alloy is left in the ſilver, the ſurface, though it may be quite brilliant, appears under the microſcope as ſmooth as if varniſhed, and ſcarcely at all ſcaly in texture.

In common aſſays of plate, either gold or ſilver, copper is the alloy uſually met with; if the fine metal be nearly pure, the cupel round the bottom is only ſtained yellow by the litharge; if copper is contained, it leaves a brown grey ſtain; the other metals, except biſmuth, ſcarcely penetrate the ſubſtance of the cupel, but remain on the edges of its cavity in the form of coloured ſcoriæ, of which iron is black, tin grey, and zinc a dull yellow.[b]

The management of the fire is a point of great conſequence in cupellation, and ſeveral important cautions are given by the moſt experienced aſſayers. When ſilver is kept in fuſion

[a] Tillet Mem. de l'Acad. 1769.

[b] Vauquelin, Manuel de l'Eſſayeur.

in a very high heat, a portion of it is volatilized, ſo that if a cupel is inverted over another containing the ſilver thus intenſely heated, the upper one will after a while be found ſtudded over with minute globules of ſilver, very viſible through a common lens. M. Tillet found that a button of pure ſilver, kept in a very high heat for two hours in a cupel, loſt no leſs than $\frac{1}{10}$ of its weight, and hence the error which this may produce in aſſaying is conſiderable, and makes a return of a metal of leſs purity than is really the caſe. The heat is known to be too great when the cupel can ſcarcely be diſtinguiſhed from the muffle, when the fume given off from the metal can hardly be ſeen for the dazzling heat, and mounts up to the dome of the muffle with great rapidity. On the other hand, when the fire is too ſlack, the litharge is not abſorbed by the cupel, but lies on the ſurface as a red ſcoria, the circulation is ſluggiſh, the button flat, and the fume very ſmall. Towards the end of the operation, the heat ſhould be gradually increaſed, for in proportion as the lead is abſtracted from the alloy, it becomes leſs eaſy of fuſion, and at laſt a heat fully equal to the melting of pure ſilver is required.

As cupellation requires a free acceſs of air, as well as a high heat to oxidate the metal, the ſtopper of the furnace immediately oppoſite the mouth of the muffle is altogether removed as ſoon as the metal is put into the hot cupel, to allow a current of external air to draw in and circulate through the muffle: but to prevent this from cooling the muffle too much, a ſmall iron platform is made to project from this orifice, on which ſeveral long cylinders of charcoal are heaped up, which, kindling on the edge of the red-hot muffle, burn with ſufficient force to heat the external air in its paſſage to the cupels. The rapidity of oxidation is in a great meaſure regulated by the degree in which the mouth of the muffle is blocked up by theſe pieces of charcoal, being the greateſt when the charcoal is no more than ſufficient to keep up a due heat within, and allows the air to paſs over it freely. The fuel of the furnace, which heats all the reſt of the muffle, is totally unconnected with the charcoal at the orifice. The furnace ſhould be made ſo that the heat of the fuel within may be readily encreaſed or diminiſhed, but at the ſame time ſhould be able to be kept up with ſteadineſs and regularity.

The ſpeedieſt method of encreaſing or diminiſhing the heat of the aſſay, when the muffle is not too much crouded with cupels, is to puſh the cupel towards the further end of the muffle, to where the heat is the moſt intenſe, being in the middle of the fire; or, on the other hand, to leſſen the heat, to draw the cupel nearer the opening of the muffle, and remove a piece or two of the charcoal from the mouth.

The time taken to perform one ſilver aſſay from putting the metal into the hot cupel to the *lightening* or purity of the button, is in general from fifteen to twenty-five minutes, but the preciſe time ſeems to be of little conſequence, the button being equally pure after a rapid as a ſlow cupellation. The danger of error from too great heat in volatilizing part of the ſilver, has been already mentioned, but at all times as much external air may be admitted into the muffle as poſſible, conſiſtent with keeping up a due heat.

The proportioning the lead to the eſtimated quantity of alloy in the ſilver to be eſſayed, is a ſubject of more importance than might at firſt be expected. An aſſay is known to have had too little lead when the button is very flat, rough at the edges, dull in colour, with blackiſh ſpots, ſtrongly adherent to the cupel, and foul with ſcoria on and about the button. But at firſt view it would ſeem to be immaterial how *much* lead is added, ſo that it be ſufficient to ſeparate all the alloy, as the whole lead, whether more or leſs, will equally be oxidated by the cupellation ſooner or later. This is ſhewn by the cupellation of lead *per ſe*, when done to aſcertain its natural quantity of ſilver, the whole readily ſcorifying in the proceſs, and leaving only a minute globule of the noble metal. But the loſs in aſſaying by uſing an exceſs of lead, is more than the mere waſte of time and fuel, and for the following reaſon: M. Tillet found by experiment that when perfectly pure ſilver was cupelled with lead, whoſe natural retent of ſilver was known, the button of ſilver remaining after the proceſs was never preciſely of the ſame weight as before, but always a certain proportion leſs, even when the heat was not ſufficient to drive off any of the ſilver. This indicated that a part muſt have been carried down by the lead into the cupel, and it was proved by afterwards reducing the oxyd of lead out of the cupel, and cupelling this lead by itſelf, when the quantity of ſilver left was found to be ten times as great as the natural proportion of this metal, and almoſt exactly to correſpond to the loſs of ſilver in the firſt inſtance. Hence it follows that the aſſayers report of the title or purity of any ſample of ſilver (unleſs corrected) always makes the metal a little leſs pure than in reality, the loſs of weight in the button being

entirely put to the account of alloy. When no more lead is used than necessary for the perfect separation of the alloy, M. Tillet reckons that it carries down into the cupel as much silver as, when the whole is again reduced, would make the noble metal $\frac{1}{1152}$ of the mass, when the natural admixture of silver is only about $\frac{1}{1152}$. But if an excess of lead is employed for cupellation, this loss of silver is somewhat greater, though it does not encrease in the ratio of the excess of the lead, for ten parts of lead to a given alloy will not carry down twice as much silver as five parts, though the difference of loss will be very sensible.

It might be supposed that as the litharge of the first assay has been able to carry down a certain portion of silver into the cupel in the first instance; the same when again reduced to reguline lead could not be made to restore its excess of silver by mere cupellation *per se*. This however is not the case, for the second cupellation is found to leave a button of silver fully equal to the loss of this metal in the first assay, the lead only carrying down its natural retent of silver or nearly, that is about $\frac{1}{1152}$ of its weight, as above mentioned. If the litharge of the second cupellation is again reduced and the lead cupelled a third time, an extremely small globule of silver is left, scarcely visible to the naked eye. Again reduced and cupelled, a minute grain of silver, only visible by a lens, is left on the cupel, after which the quantity becomes so small as to elude the senses. This is a convincing proof against the conversion of lead into silver by cupellation, formerly supposed by some chemists of considerable name, the silver being obviously only extracted from the lead in these processes, and not generated from it. In all these reductions the silver appears equally distributed through the lead, for M. Tillet found that separate globules of lead by accident spurted out upon an empty cupel in the muffle, each left a minute atom of silver lying upon the spot where the globules had scorified.

Bismuth will serve the same purpose as lead in cupellation, but besides that is a dearer metal and not always easily procurable, it is found to carry down with it into the cupel somewhat more of the silver than the same quantity of lead does.

As the lead must be proportioned before cupellation to the estimated quantity of alloy in the silver, a method must be found of forming this estimate with sufficient exactness. The antient assayers made great use of Touch-Needles, or small slips or bars of metal, made with pure silver, alloyed with known proportions of copper, in a regularly encreasing series from the least to the greatest proportion ever required. The silver to be assayed was then examined in comparison with the touch-needles, in colour, tenacity, and other external characters, and its alloy was estimated by that of the needle to which it shewed the closest resemblance. These needles are now however almost totally disused in silver assaying, an experienced assayer being able to judge of the alloy with quite sufficient exactness, by the ease or difficulty with which it is cut, the colour and grain of a fresh cut surface, the malleability, the change of surface when made red hot, and the general appearance.

Assay of Gold.

The assay of gold is somewhat more complicated than that of silver. Silver, if not mixed with gold or platina, requires only the single operation of the cupel to separate its alloy and ascertain its purity; if mixed with gold, though the latter be in a small proportion, it is called a gold assay, on account of the superior value of this metal. Copper, or any other base metal, when mixed with gold may indeed be separated from it by cupellation with lead as from silver, but it is found by experience that the affinity of copper to gold is so strong as scarcely to be overcome by this method, unless the mixture be first combined with a certain quantity of silver before cupellation. This therefore necessarily requires a subsequent operation, namely that of separating the gold from the silver when mixed in the button left after cupellation.

Gold is also frequently alloyed intentionally with silver in some foreign coins, and in some kinds of manufacture. The process of *parting*, or separating gold from silver is performed by a dilute nitric acid (or aqua fortis as it is constantly termed in manufacture) the acid dissolving the silver and leaving the gold untouched. But here another singular circumstance occurs: it is found that when the gold is in considerable proportion in the mixture, it so much protects the silver from the acid as to prevent its action more or less completely, and the parting is imperfect. Therefore, when these metals are thus mixed, it becomes necessary to add so much silver as to give this metal a great excess over the gold. About three of silver to one of gold are generally considered to be requisite, and hence the process of parting has also been called *quartation*, the relative proportion of the gold being reduced to no more than *one-fourth* of the

maſs. Any greater proportion of ſilver than three-fourths may be parted with equal certainty, but for a particular convenience in managing the proceſs and to ſave needleſs trouble, when ſilver is to be intentionally added, no more is taken than will give the above compoſition. It may be obſerved however that many good aſſayers conſider three parts of ſilver to one of gold as more than neceſſary, and that about two will ſuffice.

It would ſeem at firſt ſight that in gold aſſaying, as both ſilver and copper (the uſual alloy of gold) are ſoluble in aqua fortis, the firſt proceſs of cupellation might be ſpared, and the parting alone reſorted to. This is indeed ſometimes done, the gold aſſay piece being ſimply melted with the requiſite quantity of ſilver and immediately parted by means of the acid. But as the entire quantity of materials for the aſſay is only a few grains, and as the intimate mixture with the ſilver is a point of great conſequence, it is found better on the whole firſt to cupel them with lead (even when no copper is preſent and the original alloy of the gold is only ſilver) that they may be thoroughly combined and be collected into a ſmall neat globule, without riſk of loſing or diſperſing any minute portions.

The cupellation of gold therefore is conducted in the following manner. Its proportion of alloy being firſt eſtimated by the *touch*, as will preſently be explained, and the ſmall piece deſigned for the aſſay being weighed with extreme accuracy, as much ſilver is taken as is eſtimated to be neceſſary to make the entire quantity of this metal about thrice the weight of the pure gold; the requiſite proportion of lead is alſo taken, and all three are put on the hot cupel, where they melt and combine almoſt immediately. The proportion of lead to the alloy of baſe metal is nearly the ſame as for ſilver aſſaying, the quantity will be ſeen by the ſubjoined table. The proceſs of cupellation is conducted nearly the ſame as for ſilver, only a greater heat is required throughout in gold aſſaying, and this may be uſed with freedom, as none of the gold, or rather the mixture of gold and ſilver, is loſt by volatilization, as pure ſilver is. The *lightning*, or ſudden luminous brightneſs of the button, when all the lead is worked off, takes place here as in ſilver aſſaying, and when cooled the button is taken out and weighed. It now conſiſts only of gold, with about three times its weight of ſilver; the copper, the original alloy, having been worked off along with the litharge. Strictly ſpeaking however, the button is not abſolutely pure, as gold when cupelled with lead always retains a minute portion of this latter metal, which may be got rid of chiefly by being kept a little time in fuſion on a clean veſſel covered by a ſmall crucible. The lead totally diſappears after parting.[c] The cold button is then flattened with the hammer, again heated red hot, and ſlowly cooled to anneal it and encreaſe its malleability, then paſſed between rollers of poliſhed ſteel, to extend it into a ſmall plate about as thin as a wafer, again heated only to redneſs, and laſtly rolled up into a ſmall looſe coil. The uſe of the annealing is to allow the plate to roll up without cracking, and at the ſame time to open the texture of the metal ſomewhat cloſed by the rolling, to allow the free action of the aqua fortis in the ſubſequent operation of *parting*.

Before we deſcribe this proceſs we ſhall mention the way of eſtimating the alloy of gold before cupellation, which is neceſſary for giving it the due portion of lead. The fineneſs of ſilver, as we before obſerved, is aſcertained partly by touch-needles of ſilver and copper, but principally by the appearance, hardneſs, and other external characters which experienced aſſayers can eſtimate to very great nicety. Gold is partly judged of by the ſame method, but it is more complicated than in the former caſe at leaſt, as three metals are here concerned in the uſual alloys, namely, gold, ſilver and copper, ſo that the aſſayer has to judge of every proportion of admixture of gold and ſilver, gold and copper, and often gold, ſilver and copper. An experienced artiſt, if he knows the nature of the alloy, can nearly tell its proportion by mere inſpection and cutting the ſurface; but if touch-needles are here uſed, there muſt be ſeveral ſets of them, adapted to the nature of the alloy. Four ſets of theſe are commonly directed;[d] one in which pure ſilver is uſed for the alloy, another in which the alloy is a mixture of two parts ſilver and one copper, a third with two parts copper and one ſilver, and a fourth of copper only. Theſe are ſeverally weighed out moſt carefully, with every requiſite portion of the fineſt gold, encreaſing in twenty-fourth parts, and melted together; but with the three laſt very little uſe can be made of mixtures of low denomination, for where the copper is in large quantity, the change which it gives to the colour of gold is not eaſily diſtinguiſhed from the hue of different ſpecies of copper. In melting theſe mixtures, beſides the

[c] Tillet. [d] Lewis Comm. of Arts. p. 120.

uſual precautions againſt accidental loſs, borax is uſed as a flux to facilitate the union of the metals, and ſome pitch or tallow ſhould be kept burning on the ſurface, to prevent the loſs by oxidation of part of the copper, which would alter the intended proportions. As ſoon as ever they are melted and ſtirred together they ſhould be taken out of the fire. But Mr. Hatchett's late experiments on the alloys of gold have ſhewn that the difficulties of producing a perfectly uniform alloy of theſe metals by fuſion, are ſo great as very much to leſſen the confidence to be placed in touch-needles for the ſmaller diviſions.

Another ingenious and ſimple method is reſorted to for eſtimating the proportion of gold to all other metals (platina excepted) in any alloy. It is the operation of *touching*. For this purpoſe a tolerably hard dark-coloured, ſmooth grained, even ſtone is ſelected, ſuch as the black baſalt, (or ſome kinds of fine black pottery will anſwer very well) the piece of metal to be tried is rubbed on it backwards and forwards, ſo as to make a broad bright metallic ſtreak on the touch-ſtone, which ſhews the colour of the alloy, and may be uſefully compared with another ſtreak made beſide it by the touch-needle, to which it bears the neareſt reſemblance. The colour is heightened by being wetted before examination. In this ſimple method, and by the aſſiſtance of good touch-needles, a practiſed eye will tell to great nicety the proportion of gold when the nature of alloy is known. The Chineſe are ſaid to diſtinguiſh by this means as nearly as to the 200th part of gold in the alloy of gold and ſilver, and in the extenſive commerce of the precious metals throughout the Eaſt Indies this is ſaid to be the only method of trial commonly adopted. [e]

The nitric acid is alſo of ſingular ſervice in the trial of *touching*, and is uſed to aſcertain abſolutely the quantity of gold, whether the alloy be copper or ſilver, or any other metal except platina. This is in fact performing in the rough way a kind of parting. When the ſtreak on the ſtone has been examined by the eye, a drop of aqua-fortis is let to fall and gently ſpread over it. In eight or ten ſeconds it is waſhed off, and the effect obſerved. If the ſtreak preſerves its golden brilliance unaltered, the metal is judged to be of a certain degree of fineneſs; if it looks red, dull and coppery, it is leſs fine; if the ſtreak is almoſt entirely effaced, the metal contains very little gold, and thus by that experience, which no deſcription can teach and nothing but actual practice can give, a good aſſayer will form a very tolerable judgment of the value of his ſample.

But it is found in touching that pure nitrous acid, of whatever ſtrength, will not act in any very decided manner upon the alloy of copper and gold, when this latter metal is as much as two-thirds of the maſs, [f] and hence this proceſs is chiefly of uſe in the lower mixtures. But if a ſmall portion of muriatic acid is added to the nitrous, the activity of the menſtruum is ſo much encreaſed that any mixture below three-fourths will be acted on, and conſequently the power of this operation is much extended. Gold therefore protects the alloy from the acid to a very great degree, and this is ſimilar to what is found in parting, as the gold muſt not be more than a fourth, or at moſt a third of the maſs, to allow of the ſeparation of its alloy. The beſt acid for touching is recommended by Vauquelin to be 98 parts of nitric acid of 13.4 ſpecific gravity, 2 parts of muriatic acid of 11.73 ſpecific gravity, and 25 parts of water. This nitro-muriatic acid, it may be obſerved, does not act ſenſibly on the gold of the ſtreak on the touchſtone, the application being ſo ſhort, without heat, and eſpecially the muriatic ingredient being in ſuch ſmall proportion. Touching is particularly of uſe in judging of the value of very ſmall ſamples of gold, wrought trinkets, and ſuch pieces as cannot ſpare as much as ſix or eight grains for an aſſay. As it only gives the fineneſs of the ſurface which is abraded, caution is neceſſary where plated metal is ſuſpected, or where the ſurface is artificially made finer than the inner part.

Of Parting.

The button of gold and ſilver left after cupellation, having been laminated and rolled into a ſpiral in the way above mentioned, is called a *cornet*; it is then put into a glaſs mattraſs, of a pear-form, called a *parting-glaſs*, and about twice or thrice its weight of pure nitric acid moderately diluted (M. Vauquelin recommends 1.25 ſpecific gravity) is poured on it, the glaſs is ſet on a ſand bath or over charcoal to boil, the mouth being ſlightly covered to keep out the duſt. When warm, the acid ſoon begins to act on the ſilver, and diſſolves it with the uſual evolution of nitrous fumes. As long as the acid continues to act, the cornet is ſtudded all over with minute bubbles; when theſe diſcontinue, or unite into a few large ones, it is a ſign that the acid has ceaſed to act. About fifteen

[e] Lewis. [f] Vauquelin Manuel de l'Eſſayeur.

of twenty minutes from the time the acid boils, is required for this proceſs. The cornet is now corroded throughout, having loſt by the ſolution all the ſilver, which was from two-thirds to three-fourths of its ſubſtance: the gold retains the ſame coiled form, but is very ſlender and brittle. It is of importance that it ſhould not be broken, as it tends much to the accuracy of the buſineſs to have all the gold in one piece and not in fragments, and this is the chief reaſon why no more ſilver than abſolutely neceſſary is added before cupellation; for it is obvious that the leſs the proportion of gold in the cornet the more likely it will be to fall to pieces on the ſlighteſt agitation. The hot acid ſolution of ſilver is then poured off with great care, and freſh acid, rather ſtronger, is added to clear away all remains of the ſilver, and boiled as before, but only for five or ſix minutes. It is then decanted and added to the former ſolution, and the parting glaſs is filled with hot diſtilled water, to waſh off all the remains of the ſolution. This is decanted off, and at the ſame time the cornet, now brown, ſpongy and unmetallic in appearance, is got out by the following little manual dexterity. A ſmall crucible is inverted over the top of the parting glaſs whilſt full of water, the latter is then rapidly inverted upon the crucible, and the cornet falls ſoftly through the water down the neck of the glaſs into the crucible, where it is gently depoſited and the water carefully decanted off. The crucible is then dried and heated under a muffle to redneſs, by which the cornet ſhrinks extremely in every direction, becomes firm, regains its metallic luſtre, and when fully red hot and cooled, it appears a ſmall cornet of pure gold, with all the beautiful luſtre, ſoftneſs and flexibility of this noble metal. This is then moſt accurately weighed and the proceſs is finiſhed.

The final weight of the gold cornet indicates the abſolute quantity of this metal in the aſſayed ſample: the difference between the weight of the button after cupellation (deducting the ſilver added) and the firſt ſample is the weight of the copper or other *baſe* metal in the gold; and the difference between the gold cornet together with the ſilver added, and the button after cupellation is the quantity of ſilver alloyed with the original gold.

The ſolution of ſilver left after parting is uſually recovered by immerſing in it, when collected in quantity, ſome bright copper plates, which diſſolve and precipitate the ſilver in its metallic form. It may alſo be recovered by a ſolution of common ſalt, which converts the ſilver into luna cornea, of which when waſhed and fully dried at a heat below redneſs, 100 parts indicate 75 of ſilver. The accuracy of the aſſay may be partly verified by this method.

Aſſay Weights.

A peculiar ſet of weights have been uſed by different nations in the aſſaying of gold and ſilver, which require to be explained. The real quantity taken for an aſſay is always very ſmall, in this country generally from 18 to 36 troy grains for ſilver, and from 6 to 12 grains for gold. This is the integer, and whatever be its real weight it is denominated in England the aſſay pound. This imaginary pound is then ſubdivided into aliquot parts, but differing according to the metal. The *ſilver* aſſay pound is ſubdivided as the real troy pound into 12 ounces, each ounce into twenty pennyweights, and, for aſſaying, theſe again into halves. So that there are 480 different reports for ſilver (this being the number of half pennyweights in the pound) and therefore each nominal half dwt. weighs $\frac{1}{240}$ of a troy grain, when the entire aſſay pound is 24 grains.

The report is made according to the proportion of fine metal, thus the ſtandard ſilver of the realm is reported by the aſſayers to be 11 oz. 2 dwt. *fine*, meaning thereby that the remainder of the pound is compoſed of 18 dwt. of alloy or copper, or in other terms that there are 37 parts of ſilver to 3 of copper. The gold aſſay pound is ſubdivided into 24 carats, and each carat into 4 aſſay grains, and each grain into quarters. So that there are only 384 ſeparate reports for gold. The ſtandard for gold coin is 22 carats *fine*, and of courſe 2 carats alloy. When the gold aſſay pound or integer is only 6 troy grains, the quarter aſſay grain only weighs $\frac{1}{64}$ of a troy grain. This will give an idea how accurate muſt be the ſcales uſed for ſuch delicate operations.

Aſſayers alſo make their report upon gold and ſilver as being *better* or *worſe* than the eſtabliſhed ſtandard. Thus gold of 20 carats would be reported as *worſe 2 carats*, being that proportion leſs than the ſtandard of 22 carats. We may juſt obſerve that the ſtandard for ſilver of 11 oz. 2 dwt. fine, which long has been and is now eſtabliſhed, was interrupted from March 25, 1697, to June 1, 1720, during which interval it was raiſed to 11 oz. 10 dwt. fine, and is called *new ſterling*.[z] It is diſtinguiſhed by the ſtamp of a Britannia, whilſt the *old ſterling*,

[z] London Goldſmith's Repoſitory.

alſo reſumed ſince 1720, has the ſtamp of a lion rampant. When a mixture of gold and ſilver is the ſubject of enquiry, if the quantity of gold exceeds that of ſilver, it is called *gold parting*: if the contrary, *ſilver parting*, and the return is made accordingly, but with this diſtinction: in ſilver parting the report is firſt made on all the fine metal collectively, as if for ſilver alone, ſo if 10 oz. of fine metal be found, the aſſayer reports *worſe* 1 *oz.* 2 *dwt.* that is, 1 oz. 2 dwt. lower than the ſtandard of ſilver.

When the aſſay pound is ſubdivided, as for ſilver, in the ſame manner as the troy pound, it is obvious that all the lower denominations bear the ſame relation to each other; which is ſome little advantage in transferring the aſſay reports to real mixtures for uſe. On the contrary, the carat ſubdiviſion for gold, is confined to aſſaying, but its fractions being aliquot parts of the troy pound, the calculation for real uſe is very eaſy: as the troy pound contains 5760 grs. the carat correſponds with 240 grs. or 10 dwt. the aſſay grain or 4th of a carat with 60 troy grains, and the aſſay quarter grain with 15 troy grains. To which report, when the aſſayer has ſeparated the gold (4 oz. for example) he adds 4 *oz. gold in a lb. troy*. Whereas in gold parting he takes two equal aſſay pieces, treats one as a ſilver aſſay, and the other as a gold aſſay, to find the abſolute quantity of each metal, after which the report is firſt made on the gold ſingly, to which is added the report of the ſilver ſeparately. Thus if he finds 4 oz. of gold and 3 oz. of ſilver, he reports *worſe* 14 *carats*, (2 carats being equivalent to an aſſay ounce, and conſequently the 4 oz. of gold equal to 8 carats, which ſubſtracted from 22 carats, the gold ſtandard, leaves 14) to which report he adds *fine ſilver* 3 *oz.* But when the mixed metal contains more than half alloy, it is called *metal for gold and ſilver*, and the abſolute quantity of each reported ſeparately.

The aſſay pound, or integer, is divided in a different manner in ſeveral parts of Europe. In France before the late alteration of weights the gold aſſay was divided into 24 carats, and the carat ſubdivided into 32 parts, making an ultimate diviſion of 768 parts. The ſilver aſſay pound was divided into 12 deniers, and the denier into 24 grains, making 288 grains in the pound.

The Cologne aſſay weights, uſed in moſt parts of Germany, are the following. For gold the integer, here called a *mark*, is divided into 24 carats, and each carat into 12 grains, making 288 ultimate diviſions. For ſilver, the mark is divided into 16 loths, and the loth into 18 grains, alſo making 288 ſubdiviſions.

The Chineſe uſe the decimal diviſion for gold as well as ſilver, The integer contains 100 *touches*, and the ſimple uſe of the touchſtone will enable the experteſt dealers to aſcertain with much accuracy, to the ½ touch or 200th of the integer.

The French have of late years adopted the decimal method, conſiſtently with their general ſyſtem of decimal numeration. The integer for aſſaying (both gold and ſilver) is the *gramme*, equivalent to about 15½ troy grains, and the aſſay ſubdiviſions are the ſame as thoſe eſtabliſhed for the gramme, being tenths, hundredths, and thouſandths.

It remains to give the proportions of lead to the eſtimated alloy of fine metal neceſſary to be added for cupellation. The moſt authentic documents for this purpoſe are probably the very careful experiments of Meſſrs. Tillet, Hellot, and Macquer, which were the baſis of a regulation ſubſequently adopted by an edict of the late French government.

Copper, the uſual alloy of the fine metals, when taken ſingly is found to require from ten to fourteen times its weight of lead for complete ſcorification on the cupel. Now all admixtures of fine metal tend to protect the copper from the action of the litharge, and the more obſtinately, the greater the proportion of fine metal. So that copper with three times its weight of ſilver (or 9 oz. fine) requires 40 times as much lead as copper, with 11 parts of ſilver requires 72 of lead, and the like in an encreaſing ratio. The following is the table of the proportions of lead required to different alloys of copper, of which a few points are founded on the above-mentioned experiments, and the reſt filled up according to the eſtimated ratio of encreaſe (being mutiples of the aſſay integer 24, in arithmetical progreſſion.) In the three firſt columns is ſhewn the abſolute encreaſe of the quantity of lead in alloys of decreaſing fineneſs: in the three laſt columns will be ſeen the gradual diminution of the protecting power of fine metal againſt ſcorification, in proportion to the encreaſe of alloy ſhewn by the decreaſing quantity of lead required for the ſame weight of copper, under different mixtures.

TABLÆ.

Silver.	Copper.	Lead.	Ratio of encreaſe.	Copper.	Silver.	Lead.
23 with	1 requires	96	(= 4×24) and hence	1 with	23 requires	96
22 ——	2 ——	144	(= 6×24) ——	1 ——	11 ——	72
20 ——	4 ——	192	(= 8×24) ——	1 ——	5 ——	48
18 ——	6 ——	240	(=10×24) ——	1 ——	3 ——	40
16 ——	8 ——	288	(=12×24) ——	1 ——	2 ——	36
14 ——	10 ——	336	(=14×24) ——	1 ——	$1\frac{2}{3}$ ——	33
12 ——	12 ——	384	(=16×24) ——	1 ——	1 ——	32
10 ——	14 ——	432	(=18×24) ——	1 ——	$\frac{5}{7}$ ——	30×
8 ——	16 ——	480	(=20×24) ——	1 ——	$\frac{1}{2}$ ——	30
6 ——	18 ——	528	(=22×24) ——	1 ——	$\frac{1}{3}$ ——	29×
4 ——	20 ——	576	(=24×24) ——	1 ——	$\frac{1}{5}$ ——	28×
2 ——	22 ——	624	(=26×24) ——	1 ——	$\frac{1}{11}$ ——	28×

It ſhould be remarked however, that many aſſayers of good authority uſe proportions of lead to alloy conſiderably different from the above table, and the whole of the numbers here given may be conſidered as rather high in regard to the quantity of lead.

The German aſſayers obſerve the following rules. [h]

Copper.	Silver.	Lead.
1. with	30 requires	128
1 ——	15 ——	96
1 ——	7 ——	64
1 ——	4 ——	56
1 ——	3 ——	40
1 ——	1 ——	30
1 ——	$\frac{1}{3}$ ——	20
1 ——	$\frac{1}{15}$ ——	17

The proportions of lead required for gold aſſaying are nearly the ſame as for ſilver.

Aſſays of alloys of Platina.

On account of the great ſpecific gravity of platina, it has ſometimes been fraudulently employed as an alloy for gold, and being equally unoxidable by lead as gold and ſilver, it remains in the aſſay button after cupellation. It is not difficult however to detect this metal even in very ſmall admixtures, and by the following marks. Gold alloyed with ſo little as 1 per cent of platina, and cupelled in the uſual way with 3 parts of ſilver, differs from gold and ſilver alone.

1. In requiring a much greater heat for compleat fuſion of the button, eſpecially at the laſt when all the lead is worked off, otherwiſe the button remains flat, like a piece of money, and its ſurface knotty.

2. Even when the button is well fuſed, its edges are much thicker and more rounded than in common gold aſſays, its colour duller and tending to yellow, and eſpecially it appears remarkably and entirely cryſtallized on its ſurface. This power of platina in giving a decided cryſtalline form to the gold or ſilver alloys in which it enters, is very characteriſtic.

3. In the cupellation, as ſoon as the laſt portions of lead are worked off, the button appears ſomewhat paſty, is ſcarcely irideſcent, and eſpecially it does not *lighten* or aſſume ſuddenly a brilliant metallic look, but remains dull and tarniſhed.

Theſe appearances encreaſe with the quantity of platina in the alloy, but when it amounts to about 10 per cent. the colour of the alloy is ſo debaſed and whitened as readily to be diſtinguiſhed from that of pure or ſtandard gold, by ſimple inſpection.

Silver is ſeldom alloyed with platina intentionally, the price of the two metals being ſo nearly the ſame as not to make it worth while as a fraud. When the platina is not more than 5 per cent. of the alloy, it works eaſily on the cupel, but the *lightning* is leſs obſervable than in a button of pure ſilver. But the remarkable property of cryſtallizing is ſtill more conſpicuous here than in the compound alloy of gold ſilver and platina, and the button is beſides of a duller white, with ſomewhat of yellow. When the platina amounts to a quarter of the alloy, the button on the cupel flattens and becomes paſty, even before all the lead is run off; its ſurface becomes full of knobs, which by help of a glaſs appear cluſters of cryſtalline points, and its colour is grey and tarniſhed.

The action of nitrous acid on the alloys of platina is very remarkable. By itſelf platina is inſoluble in this acid as gold is, and an alloy of theſe two metals equally reſiſts its action. But when ſilver enters into the mixture in the

[h] Gren. Syſt. Handb.

ſame proportion as for parting (that is about 2½ or 3 times the weight of the gold and platina) and when the platina is not more than about a tenth of the gold, the platina is totally ſoluble in nitrous acid, together with the ſilver, and the gold alone remains untouched.

On the other hand when an alloy of ſilver and platina alone is treated with nitrous acid, the ſilver diſſolves as uſual, but the liquor ſoon becomes muddy, with a very fine bulky black precipitate, which continues encreaſing till all the ſilver is diſſolved, and when collected is found to be entirely platina, comminuted by the acid, but ſcarcely changed in any other reſpect. A part of the platina however remains in perfect ſolution, for on adding to the liquor, ſeparated from the black precipitate, ſome muriatic acid, white luna cornea falls down, after which carbonat of potaſh will throw down a green coagulum, which is oxyd of platina.[i] The above effect of nitrous acid will therefore detect an alloy of ſilver and platina.

Gold alloyed with platina may be entirely purified (as we have juſt mentioned) by the proceſs of parting with aqua-fortis, the alloy being as uſual previouſly mixed with two or three times its weight of ſilver. Some peculiar circumſtances are required in the operation. The mixed metal being laminated very thin and rolled into a ſpiral cornet, a weak acid is firſt added and boiled for ſome time. If the platina is above 2 per cent of the gold, the acid aſſumes a ſtraw colour,[k] which deepens in proportion to the platina, and at the ſame time the cornets take a browniſh green. A ſtronger acid is then added and boiled three times ſucceſſively, to detach the laſt portions of platina, which are with difficulty ſeparated, and by a magnifying glaſs may be ſeen adhering in minute grains to the ſurface of the gold cornet. Thus by laminating very fine, and by uſing the acid liberally, and long boiling, all the platina may be ſeparated at one operation, when it does not exceed a tenth of the gold, and above that proportion the colour of the gold is ſo much debaſed, and the appearances on cupellation are ſo ſtriking, that the fraud can hardly eſcape an experienced eye. Even if more than a tenth of the gold alloy, the platina may ſtill be ſeparated very completely by parting, but in that caſe more ſilver muſt be added, which will reduce the proportion of gold ſo much, that after the action of the acid the cornet can hardly be annealed without breaking down and loſing its form.

For further particulars concerning the weights uſed by Aſſayers in different countries ſee Appendix: article WEIGHTS and MEASURES.

ASTRINGENT *(Vegetable)*. Till the later experiments on vegetable ſubſtances had ſhewn the important diſtinctions between the tanning principle, and the acid, which from its being firſt extracted from galls has been termed the *Gallic*, that part of vegetables which has the power of tanning leather, and that which ſtrikes a deep inky black with the ſalts of iron, were both confounded under the general term *aſtringent principle*, taken from the ſenſible quality of aſtringency to the tongue. They are now found to be totally diſtinct, and will be deſcribed reſpectively under the articles TANNIN and GALLIC ACID.

ATHANOR. A ſpecies of furnace much uſed by the antient chemiſts, but now moſtly laid aſide. *(See in the Appendix Chemical Apparatus.)*

ATMOSPHERIC AIR. *Gas atmoſpherique*, Fr. *Atmoſphariſche luft*, Germ.

Atmoſpheric air is an elaſtic inviſible fluid, of the ſpecific gravity of .001204, at the temperature of 60° Fahr. the barometrical preſſure being equal to 29.5.[a] A cubic inch of air weighs 0.304 grains, a cubic foot 5253. grains, and it is 830 times lighter than water. Being elaſtic, its ſpecific gravity or denſity depends upon, and is in proportion to, the force by which it is compreſſed, therefore the denſity of the air above the ſurface of the earth decreaſes in a geometrical ratio, as the heighth increaſes in an arithmetical one. If at the ſurface of the earth the denſity of the air correſponds to 30 inches of barometrical preſſure, then at

feet.		inches.
1000	the mercury is	28.91
2000	———	27.86
3000	———	26.85
4000	———	25.87
5000	———	24.93
1 mile	———	24.67
2	———	20.29
3	———	16.68
4	———	13.72
5	———	11.28
10	———	4.24
15	———	1.60
20	———	0.95[b]

Air, like all other bodies, is expanded by heat, and the quantity of expanſion being very conſiderable, it is of importance to the accuracy of chemical experiments on this ſubſtance to

[i] Tillet. [k] Vauquelin, Tillet. [a] Fletcher, in Nicholſon's Journ. iv. p. 35. [b] Rees's Cycloped. art. Barometer.

have it ascertained with precision. From the nearly concurring results of Gen. Roy's experiments, and those of Sir G. Shuckburg, it appears that the air measures in bulk $\frac{1}{480}$ for every degree of Fahrenheit between 32° and 72°. Mr. Dalton finds [c] that 1000 parts of air at the usual barometrical pressure, and 55° of temperature, dilate to 1325 when raised to 212° Fahr. he is also of opinion that the ratio of dilatation is a gradually decreasing one as the temperature descends.

The colour of the air when free from clouds is a blue, of greater or less intensity. Near the surface of the earth it is diluted by the white rays of light that are reflected from the aqueous vapour that is constantly floating in the lower regions of the atmosphere, but in proportion as the observer is elevated above these vapours, the colour of the sky assumes a more intense blue. Saussure [d] observes that the sky from the summit of Mont-Blanc appeared of a deep almost black prussian blue.

The chemical properties of atmospheric air were but little attended to till about thirty years ago; but before we give an account of the modern discoveries on this subject, it will be right to take a short view of what had been previously done by two eminent philosophers, Boyle and Mayow; the latter of whom has been consigned to unmerited neglect for more than a century, although the most profound observer of his time.

The apparatus which Boyle [e] made use of in his experiments was the air-pump, an instrument with all its modern improvements but very imperfectly fitted for the chemical examination of elastic fluids, and at that time a huge cumbersome machine, worked by the constant labour of two men, and imbibing air at every pore. By the help of this instrument, Boyle ascertained that the presence of air was essential to the support of flame and animal life, a candle being extinguished, and various small land animals, and even fish in water, being killed by being placed in an exhausted receiver. He also shewed that the same effects take place, but more slowly in a confined portion of atmospheric air, and that the death of animals in this situation was not owing to the heated exhalations from their own bodies, since the same effects took place when the apparatus was transferred to a frigorific mixture. He proved besides that animals live longer in a given bulk of condensed than of common air. He did not believe however that any absorption of air took place in respiration, or that the pure atmosphere was a compound substance.

Mayow published his Medico-physical tracts a few years after Boyle, and a century before the discovery of oxygen gas by Priestley and Scheele. This able, though much neglected philosopher, commenced his investigations into the nature of atmospheric air by the invention of a proper apparatus; for this purpose, rejecting the use of the air-pump, he made choice of glass jars inverted in water, as the best method of confining the gasses that were submitted to examination. Setting out from the facts discovered by Boyle, he argues that since a candle is extinguished much sooner in an exhausted receiver than in the same when filled with air, there must be something in the atmosphere necessary to the continuance of flame. This is further proved, says he, from the impossibility of kindling a combustible body *in vacuo*, by the concentrated rays of the sun, or by any other means. Having established this first position, he proceeds to infer that it is not the whole of the air which is capable of supporting flame, because a candle goes out in confined air, while the greatest part of the air is as yet unconsumed. Also since sulphur when mixed with nitre becomes capable of inflammation *in vacuo*, it follows that nitre and air contain some substance in common to which this property is to be attributed. This substance he denominates *igneo-aerial particles* (particulæ igneo-aereæ). He next determined the analogy between flame and animal life, and shewed that each depended for its continuance on a supply of igneo-aerial particles. That there was a real consumption of air in combustion and respiration, he proved by the rise of water in the jars in which a live animal or a lighted candle was confined; and that the diminution was owing to the abstraction of the igneo-aerial part, appeared from the inability of the residue to support animal life. With regard to the relative proportions of the atmosphere, he only observed that air rendered unfit for combustion by the breathing of an animal, lost about one-fourteenth of its bulk; at the same time remarking that there was probably only a part of the igneo-aerial portion of the air consumed. But Mayow never obtained the igneo-aerial particles in a separate state, and therefore was unable to confirm his analysis of atmospherical air by the synthetical proof. [f]

The next advance in the decomposition of

[c] Manchester Mem. vol. v. p. 509. [d] Voyages dans les Alpes, vol iv. § 2009. [e] Boyles Works, v. ii.
[f] Mayow, Tractatus quinque medico-physici.

atmoſpherical air was made by Dr. Prieſtley.[g] This philoſopher having incloſed ſome *mercurial precipitate per ſe*, in a jar filled with mercury, and inverted over the ſame, procured from it by means of heat, a quantity of gas, in which a candle burnt with a dazzling and enlarged flame: the coincidence of this with the effect produced by dephlogiſticated nitrous gas in the ſame circumſtances, as had been before obſerved by him, induced him to believe that there was ſome common principle in nitrous acid and atmoſpherical air, and this ſuſpicion was ſtill further confirmed by the diſcovery that common *red precipitate*, which is prepared by means of nitrous acid, yielded dephlogiſticated air in the ſame manner as the precipitate *per ſe*. Hence he concluded that the atmoſphere conſiſted of this pure, or vital, or dephlogiſticated air, mixed with a variable portion of phlogiſton.

While Dr. Prieſtley was making theſe experiments, the acute and accurate Scheele[h] was purſuing the ſame courſe of inveſtigation, though in a different manner. He obſerved that phoſphorus, and the watery ſolutions of the earthy and alkaline ſulphurets, when confined with a given quantity of air, had the property of abſorbing about a third or a fourth of its bulk, and left the remainder unable any longer to ſupport flame or animal life, which in conſequence was called by him *foul air*. By expoſing nitre, the black oxyd of manganeſe, and ſome other ſubſtances to a red heat, he obtained from them a quantity of the ſame kind of air as Dr. Prieſtley's dephlogiſticated, but which was called by him *pure air*; and this when mixed in the proportion of one part to two of foul air, formed an elaſtic fluid, which could not be diſtinguiſhed from atmoſpheric air. Scheele therefore concluded that the atmoſphere is compoſed of two different ſubſtances, pure air and foul air, or according to the modern nomenclature, of oxygen and azot, in the proportion of one of the former to two of the latter.

The experiments of Scheele were ſoon confirmed by the concluſions of Lavoiſier,[i] from ſomewhat different premiſes. He confined a few ounces of mercury, and about 50 cubical inches of atmoſpherical air, in a proper glaſs apparatus, and expoſed the mercury for twelve days, to a heat nearly equal to that of ebullition; during this period 45 grains of red oxyd of mercury were produced, between ſeven and eight inches of the air diſappeared, and the remainder was incapable of ſupporting flame and animal life. The 45 grains of red oxyd being then heated in a very minute retort, were wholly decompoſed into 41 grains of running mercury, and ſeven or eight cubic inches of pure oxygen gas; finally this gas being mixed with the reſidual air in the firſt part of the experiment, produced a compound, poſſeſſing nearly the ſame power of ſupporting combuſtion and reſpiration as atmoſpheric air. Hence it appears that atmoſpheric air conſiſts of 16 per cent. of oxygen and 84 of azot.

Various inſtruments called EUDIOMETERS (which ſee) have ſince been invented for aſcertaining in a commodious and accurate way the quantities of oxygen and azot in common air, ſeveral unexpected ſources of error have been diſcovered and obviated, and by the lateſt and moſt unexceptionable experiments, the relative proportions of oxygen and azot appear to be 22 of the former and 78 of the latter,[k] in bulk, or 26 oxygen and 74 azot, if eſtimated by weight. Concurring experiments alſo have been made with the greateſt care in Egypt and every part of Europe, from which the general concluſion is, that neither climate nor temperature, nor diſtance above the ſurface of the earth, produce the ſmalleſt variation in the relative quantities of theſe gaſſes, which compoſe ſo large a proportion of the whole atmoſphere.

The only remaining ſubſtance, except water, which has hitherto been detected in common air, is carbonic acid: it is found not only in that ſtratum which immediately reſts upon the ſurface of the earth, where from its ſuperior ſpecific gravity it might be expected to continue, but was found by Sauſſure to enter into the compoſition of the air at the ſummit of Mont-Blanc, about 5000 yards above the level of the ſea.[l] The proportion of this gas to the other two already mentioned, has not been determined with the deſired accuracy; according to Humboldt it varies from 5 to 1 per cent. but the general average, from the experiments of other chemiſts, does not exceed 2 per cent. and it is probable that this ratio is neareſt to the truth.

ATMOSPHERICAL *Mephitis*. A term given by ſome to the air now called AZOT.

ATTRACTION (*Chemical.*) See AFFINITY.

AUGITE. *Augit*, Werner. *Pyroxène*, Hauy.[a] The colour of this mineral is generally a dark green, paſſing ſometimes into leek-green and liver brown. It occurs diſſeminated in ſmall irregular grains or cryſtallized. The primitive

[g] Experiments on Air. [h] Scheele, on Air and Fire. [i] Lavoiſier's Elements of Chemiſtry, p. 80.
[k] Thompſon's Chim. 2d edit. vol. iii. [l] Voyages ſur les Alpes. [a] Emmerling, Jameſon, Hauy, Brochant.

form of the mineral is an oblique rhomboidal prism, of 92° and 88° divisible parallel to the sides of the prism, and also in the direction of the long diagonal of the base into two oblique triangular prisms.

The chief varieties of crystallization to which it is subject are the following.

1. A short rectangular six-sided prism (perihexaëdre of Hauy.)

2. The same terminated by dihedral summits (bisunitaire of Hauy.)

3. An octahedral prism, formed by bevilling the acute edges of the six-sided prism (perioctaedre of Hauy.)

4. The preceding terminated by dihedral summits (triunitaire of Hauy.)

5. The preceding with the summit bevilled (sexoctonal of Hauy.)

6. The same as var. 4. having the acute solid angle of the summit replaced by a triangular horizontal facet (soustractive of Hauy.)

7. Two or more crystals crossing each other (hemitrope of Hauy.)

The crystals are in general very small, the largest, about an inch and a half in length, have been found at Arendahl, in Norway.

The fracture of augite is uneven, passing into conchoidal, or foliated: its lustre is resinous and shining, approaching in some specimens to brilliant. It is translucid, the conchoidal varieties however are often semitransparent. It is sufficiently hard to scratch glass. Sp. gr. 3.22 to 3.47. It gives a green streak.

In small pieces it is difficultly fusible before the blowpipe into a black enamel. The constituent parts of the augite from Etna, according to the analysis of Vauquelin, are

52.	silex,
13.2	lime,
3.33	alumine,
10.	magnesia,
14.66	oxyd of iron,
2.	—— of manganese.
95.19	
4.81	loss
100.	

Augite is distinguished from Olivine by its darker colour, greater hardness and crystalline form; from hornblende in being diagonally divisible into triangular prisms, and in being much less fusible; from tourmaline in not being electric by heat and being more difficultly fusible.

It is found in basalt, often accompanied by olivine, in Bohemia, Transilvania, Hesse, Saxony, Auvergne, Scotland and Norway. It is also found imbedded in the lavas of Etna and Vesuvius, and when in this situation is not unfrequently of a grey or white colour, a somewhat harsh feel, little or no lustre, soft and brittle, by having been exposed to the action of the fire: in some specimens these changes are only superficial, the nucleus exhibiting the genuine characters of augite, as above described.

AURUM FULMINANS. A precipitate of Gold from its nitro-muriatic solution by ammonia, which possesses a most remarkable explosive property.

AURUM Graphicum, Problematicum. See Tellurium.

AURUM MUSIVUM. A golden-coloured *sulphuret of* Tin.

AVENTURINE. See Quartz.

AVIGNON-BERRY. The berries of the *Rhamnus Infectorius* (Nerprun des Teinturiers,) are used considerably in the middle and south of France, to give a yellow dye. They are gathered unripe, bruised, steeped and then boiled in water, mixed with the ashes of vine stalks to give a body, and then passed through fine linen. The colour thus prepared is called *stil de grain*. It is a fine yellow chiefly used in silk-dying, but is very fugitive especially in the sun. The plant grows abundantly about Avignon, and in the south of France. [a]

AXINITE. See Thumerstein.

AZOT or *Nitrogen*. *Stickgas*, Germ.

This gas (the *phlogisticated air* of Priestley) forms the unrespirable part of atmospheric air, and exists in it in the proportion of about 78 per cent. estimated by bulk, or 74 per cent. by weight.

The properties, by which this air was first distinguished, were principally negative, and in direct opposition to those of *oxygen*, the other constituent of the atmosphere; the latter supporting combustion in an eminent degree, maintaining animal respiration, oxydating metals, &c. whilst the former was found to be immediately fatal to animals immersed in it (whence its name *azot*), to extinguish flame instantly, and to produce no change on combustible bodies immersed in it.

Azot is readily procured from atmospherical air by all the following processes, which absorb its oxygenous portion, and which are more fully detailed under the article Eudiometry. If iron filings and sulphur, in equal parts, are

[a] Nouveau Dict. d'Hist. Nat.

worked up into a paſte with water, and introduced under a jar of common air confined over water, a gradual abſorption of the oxygen takes place, which is complete in about two days, and the reſidue is azotic gas in great purity. After the diminution of air has ceaſed, the iron filings and ſulphur ſhould be removed, otherwiſe ſome ſulphuretted hydrogen will be evolved, and the azotic gas ſhould in all caſes be agitated with lime water or cauſtic alkali, to abſorb any carbonic acid with which it may be mixed, after which the azot is pure.

Azot may be inſtantly obtained from common air by adding juſt ſo much pure nitrous gas as will deſtroy the oxygen and no more, or better, by agitating common air with a ſolution of ſulphat of iron ſaturated with nitrous gas. The reſidue is then very pure azot. Or it may be obtained by another eudiometric proceſs, namely, by abſtracting the oxygen from common air by means of phoſphorus. In this caſe however the remaining azot diſſolves a ſmall portion of the phoſphorus, ſufficient to render it luminous on mixing with it the ſmalleſt portion of oxygen.

Azot is a conſtituent part of almoſt all ANIMAL ſubſtances, and is the cauſe of the production of *ammonia*, when they are heated to diſorganization or during putrefaction. It forms at the ſame time a conſtituent part of this alkali.

The production of azot in the form of gas from animal matter is ſhewn in the following way. Put ſome of the lean of any meat (beef for example) into a glaſs veſſel with a bent tube, pour thereon ſome very dilute nitric acid, and apply a heat of about 100°. Bubbles of gas will ſlowly ariſe, which when collected and examined are found to be pure azot. The azot in this caſe does not proceed from the nitric acid, as this appears to be able to ſaturate as much alkali after the proceſs as before, and hence it ſeems only to effect a decompoſition of the meat, though in a way that is not very apparent.

Azot is however a conſtituent of the NITRIC acid, as was firſt ſhewn by the beautiful and deciſive experiments of Mr. Cavendiſh, who by means of the electric ſpark combined azotic and oxygenous gaſſes, and the reſult of this union was found to be the nitric acid. By this moſt important diſcovery it is explained how the putrefaction of animal matters in certain ſtages is ſo favourable for the production of nitre, with many other phenomena to be deſcribed in their place. From this combination of azot, the term *nitrogen* (or the baſe of nitric acid) has been adopted by ſome chemiſts, and is certainly preferable to the other, which only implies the general property of deſtroying life, a property poſſeſſed in a greater or leſs degree by every gaſeous body in nature, oxygen and ſome of its combinations excepted. Azot in its different ſtages of oxydation becomes *nitrous oxyd*, *nitrous gas*, and *nitric acid*, all very intereſting ſubſtances in their chemical properties.

Azot has hitherto never been decompoſed (all the ſuppoſed experiments to this purpoſe having been found fallacious), and hence it muſt be conſidered as a ſimple body. When pure it is lighter than common air nearly in the proportion of 98 to 100, ſo that if a cubic inch of the former at 60 therm. and 29.5° bar. weighs .304 of a grain, a cubic inch of azot, under the ſame circumſtances, will weigh .2994 of a grain, and its ſpecific gravity is about .001199.

Water abſorbs not quite $\frac{1}{38}$ of its bulk of this gas aſſiſted by agitation, Mr. W. Henry having found that at 60° 100 meaſures of water could take up no more than 1.47 meaſures.[b] All common experiments therefore may be made with this gas over water, without riſk of much inaccuracy. This ſolution of azot in water ſhews neither acid nor alkaline properties, nor does azot by itſelf, or in ſimple combination with water or any other fluid, give any ſmell, taſte, or ſenſible quality.

In chemical analyſis azot is detected chiefly by its negative properties. A gas may be concluded to be azot which inſtantly extinguiſhes a taper immerſed in it, and at the ſame time is not ſenſibly abſorbed by water or liquid alkali, nor renders lime-water turbid; which does not blacken the ſolutions of lead or ſilver; which mixes with oxygen in any proportion without diminution or the production of red fumes; and when ſo mixed, does not explode by the contact of a lighted body, but allows the burning ſubſtance to conſume quietly in it, and as long as in common air, when the proportions of it to oxygen in the mixture have been taken at about 78 to 22.

The affinities of azot are unknown.

AZOT *Gaſeous Oxyd of*. See NITROUS OXYD.

AZURE. *Azure* or *azure blue* is a term applied to two very different ſubſtances. Formerly it was uſed for the fine blue colour prepared from *ultramarine* or *lapis lazuli*, but now more commonly it is applied to the deep blue glaſs of cobalt, called alſo *ſmalt*, and in Saxony *zaffre*. In maſſes the blue glaſs is named ſmalt, but when ground to fine powder, it is called by the French *bleu d'azur*. It is uſed as a colour, and in enamel painting, and alſo mixed with ſtarch for domeſtic purpoſes. See COBALT.

[b] Ph. Tranſ. 1803.

B

BALLOON. A globular glaſs veſſel with a narrow neck, a common article of *chemical apparatus*. *(See the Appendix.)*

BALNEUM. See BATH.

BALSAM *(Vegetable)*. The term balſam was antiently applied to any ſtrong ſcented natural vegetable reſin of about the fluidity of treacle, inflammable, not miſcible with water without addition, and ſuppoſed to be poſſeſſed of many medicinal virtues. All the turpentines, the Peruvian balſam, Copaiba balſam, &c. are examples of the natural balſams. Beſides, many medicines compounded of various reſins or oils, and brought to this conſiſtence, obtained the name of balſam.

Latterly however the term has been reſtricted to thoſe reſins which contain the benzoic acid. Of theſe only three are commonly known, the Gum *Benzoin*, *Styrax* and Balſam of *Tolu* (which ſee).

BARBADOES TAR. See BITUMEN.

BARILLA. The impure CARBONAT *of Soda* in the ſtate in which it is imported from different parts of Europe.

BARKS *of Trees*. See WOOD.

BAROLITE. See WITHERITE.

BAROSELENITE. See HEAVY SPAR.

BARYTES. *Baryte*, Fr. *Schwererde*, Germ. This earth is never found pure in nature, but always in combination either with the ſulphuric acid, forming the native SULPHAT of Barytes or HEAVY SPAR; or combined with the carbonic acid into CARBONAT *of Barytes* or WITHERITE.

Pure barytes is always prepared either directly from the native carbonat, or from the artificial carbonat produced by a previous decompoſition of the ſulphat of barytes. The latter is the moſt frequent, as the ſulphat is very generally diffuſed over the globe, whereas the native carbonat has been only found hitherto in England and in Siberia.

Sulphat of barytes is decompoſed by ſeveral proceſſes, all of which deſerve notice.

§ 1. Mix ſulphat of barytes in fine powder, with not leſs than twice (and better three times) its weight of dry carbonat of potaſh, and heat the mixture moderately red for at leaſt half an hour, in an earthen or ſilver crucible. Pour out the melted maſs, and when cold, powder it, and boil with water repeatedly, till the water no longer taſtes ſaline. The ſoluble part of this maſs is ſulphat of potaſh, ariſing from the decompoſed ſulphat of barytes, with ſome undecompoſed carbonat of potaſh. A white inſoluble reſidue chiefly *carbonat of barytes* remains, from which the pure barytes is prepared in the way to be preſently mentioned.

§ 2. Mix finely powdered ſulphat of barytes with at leaſt twice its weight of carbonat of potaſh,[a] and five or ſix of water, and boil in a metal, earthen, or glaſs veſſel for about an hour, adding water occaſionally to ſupply the loſs by evaporation. Pour off the liquor, which is chiefly ſulphat of potaſh, and waſh the reſidue as before. It conſiſts of carbonat of barytes, mixed with undecompoſed ſulphat, in greater quantity than by § 1. A repetition of the proceſs (the carbonat of barytes being firſt ſeparated from the reſidue by muriatic or nitric acid) will further decompoſe the remaining barytic ſulphat, but with much more difficulty than by fuſion.

§ 3. Mix ſulphat of barytes with about a ſixth of its weight of powdered charcoal, and calcine with a moderate red heat for half an hour in an *earthen* (not ſilver) crucible. By this the ſulphat is chiefly converted to a ſulphuret of barytes, eaſily ſoluble in water. Diſſolve, and add to the clear watery ſolution, which is ſulphuret of barytes, liquid carbonated ſoda, as long as any white precipitate falls down. This precipitate is carbonat of barytes, the liquor is now ſulphuret of ſoda, which is uſeful for many purpoſes of the laboratory. If the ſolution of ſulphuret of barytes is concentrated when hot, it cryſtallizes on cooling, and therefore the ſolution ſhould be ſo dilute as not to cryſtallize.

Another method is to add to the liquid ſulphuret prepared as above mentioned, ſome concentrated muriatic acid. This unites with the barytes and remains in ſolution, whilſt part of the ſulphur falls to the bottom, and part flies off in a moſt copious emiſſion of ſulphuretted hydrogen, which follows the addition of the acid. The muriated barytes may then be decompoſed by a carbonated alkali, which will leave a pure carbonated barytes.

§ 4. La Grange[b] has deſcribed another method of obtaining muriated barytes, from which the carbonat may be procured as above. This is by muriated lime and ſulphat of barytes, which decompoſe each other mutually. For this, take the reſidue from the diſtillation of muriated

[a] Klaproth's Eſſays, vol. i.

[b] Ann. Chim. tom. 47.

ammonia (which is muriated lime with exceſs of earth), lixiviate it and evaporate the clear liquid to dryneſs. It is then ſaturated muriat of lime (and of courſe any other ſoluble muriated lime will anſwer as well) which reduce to powder, and mix with its own weight of ſulphat of barytes. Project the mixture by ſpoonfuls into a red-hot crucible, and let the whole remain in quiet fuſion for a few minutes. Then pour it out while hot, and it will be a grey or often ſlate-coloured, hard, ſonorous maſs, very deliqueſcent. Diſſolve it in about ſix times its weight of boiling water, and filter. Evaporate the clear ſolution till a pellicle appears on the ſurface, then ſet it by to cryſtallize. By cooling, very fine large cryſtals of muriated barytes will be formed, which will be very diſtinguiſhable by their ſize and whiteneſs. Take them out, evaporate further to obtain a ſecond crop of cryſtals of the ſame, then rediſſolve the whole, and cryſtallize a ſecond time by evaporation and cooling. A third cryſtallization is perhaps required to ſeparate all the ſulphat and undecompoſed remainder of muriated lime.

This proceſs appears very good, but is more particularly calculated for thoſe caſes where only the muriated barytes is wanted, and not the carbonat by its means.

The carbonat of barytes thus artificially obtained, as well the native carbonat, is converted to pure barytes in two ways, firſt, by calcination, ſecondly, by being diſſolved in the nitric acid, and the nitrat afterwards heated ſtrongly, till all the acid is driven off. In either caſe the barytes will be pure.

1. A great difference is obſerved between the natural and artificial carbonats in the power of retaining their carbonic acid when ſtrongly heated. The artificial yields its carbonic acid and calcines nearly with the ſame eaſe as limeſtone, but the natural can ſcarcely by any moderate heat be made to give out its carbonic acid. Another inconvenience too ariſes in the calcination, namely, that barytes acts ſo powerfully as a flux upon clay and all other earths, that when ſtrongly heated, in proportion as it loſes its carbonic acid, it diſſolves the clay crucible, and the whole runs together without much difficulty into a hard greeniſh glaſs. [c] The native carbonat, heated moſt intenſely in a platina crucible for many hours, at 136° of Wedgewood, was found by Klaproth to have loſt only half its carbonic acid, and to adhere ſo ſtrongly to the crucible as ſcarcely to be detached by boiling water, in which pure barytes is readily ſoluble. In a charcoal crucible the native carbonat heated moſt intenſely was found by the ſame eminent chemiſt to be never entirely calcined, but always to have penetrated the ſubſtance of the charcoal and collected at the bottom in a ſemifuſed maſs.

It is therefore only the artificial carbonat which can be calcined without addition; but Pelletier [d] has diſcovered an eaſy method by which both the natural and artificial may be totally and ſpeedily deprived of carbonic acid. Mix the carbonat of barytes with a tenth of its weight of charcoal powder, make it up into a lump with paſte or ſtarch, or any mucilage, drop it into a crucible lined with charcoal, cover it with charcoal powder, and lute a cover to the crucible. Heat the whole very ſtrongly for an hour (probably half the time would ſuffice), and when cold the lump will be found to have retained its form, and to be white, friable, not vitrified, and entirely ſoluble in warm water, excepting a ſmall remaining portion of charcoal. It is now pure barytes. By this ingenious method (which will apply with advantage to all the earthy carbonats) the barytes is prevented from acting on the crucible, and the carbonic acid eſcapes chiefly in the form of *gaſeous oxyd of* CARBON.

2. The other method of preparing pure barytes is by calcination of the nitrat of barytes. The native carbonat is ſcarcely acted on by concentrated nitric acid, but when conſiderably diluted the ſolution goes on rapidly with extrication of carbonic acid gas, and a clear ſaturated nitrat is obtained. The artificial carbonat is directly diſſolved in this acid with copious efferveſcence, but if abſolute purity is required ſome precautions are neceſſary, as native ſulphat of barytes generally contains a ſmall admixture of ſtrontian, of oxyd of iron, and of ſilex. Theſe all remain in the reſidue of § 1. which therefore conſiſts chiefly of carbonat of barytes with the above impurities in ſmall quantity, together with any ſulphat of barytes that may remain undecompoſed. To this reſidue firſt add acetous acid, [e] which diſſolves out only the carbonats of barytes and ſtrontian, and the iron. Evaporate this ſolution till it is quite of a ſyrupy conſiſtence, then add concentrated nitric acid. A copious depoſition of ſmall cryſtals of pure nitrated barytes now appears, leaving the ſtrontian and iron in ſolution, the reaſon of which is, that the barytic nitrat is much leſs ſoluble than the nitrats of ſtrontian or iron, and therefore cannot be held in ſolution in ſo ſmall a

[c] Klaproth. [d] Memoires, tom. 2. [e] Lampadius's Handb. zur Ch. Analyſe.

bulk of liquid. Collect theſe cryſtals of nitrated barytes, and waſh them with a little cold water, and they are now pure.

The nitrated barytes, either cryſtallized or merely evaporated to dryneſs (according as more or leſs nicety is required in the preparation) is then to be heated in a porcelain retort, or earthen crucible ſlightly covered, to prevent any of the fuel from falling in. It preſently melts, ſwells up and gives out much azotic and oxygen gas, with a little nitrous vapour. The heat is to be continued at a moderate redneſs, till no more vapour or gas of any kind ariſes, when the reſidue will be found to be pure barytes, in the form of a grey ſomewhat porous maſs, and if the heat has been too ſtrong, partly fuſed with and adhering to the ſides of the crucible. A conſiderable time is required to deſtroy all the nitric acid, when no more heat is uſed than the crucible will allow of, but a platina crucible is preferable, as the heat may be given freely without danger of vitrifying the barytes, which would render it inſoluble in water.

Barytes prepared in either of the above methods has the following properties: its taſte is like that of lime, but much more acrid and cauſtic; and it changes the vegetable colours as the alkalies do. When a little water is added it abſorbs it with great avidity, giving out much heat, and becomes a ſtiff paſte, which ſoon ſolidifies and adheres ſtrongly to glaſs.[f] A further quantity of water changes it to a bulky white powder, which readily diſſolves, eſpecially when heated, and on cooling it has the remarkable property of cryſtalling in cluſters of tranſparent needles. No other earth but barytes and ſtrontian can be thus artificially cryſtallized.

Barytes is extremely ſoluble in water: when boiling, water diſſolves more than half its weight, the greater part of which cryſtallizes on cooling, for cold water diſſolves only a twenty-fifth of its weight. Slowly cooled, the cryſtals are fine tranſparent priſms.

Barytes when heated on charcoal, by the blowpipe becomes hard and ſemivitrified in texture, and is ſcarcely again ſoluble in water. It ſeems to return by this proceſs partly to the ſtate of carbonat, gaining carbonic acid from the flame of the lamp. When the blowpipe is urged with oxygen gas, barytes readily melts into a white enamel-like globule.

Barytic water (or a ſolution of barytes in water) reſembles limewater in abſorbing carbonic acid from the atmoſphere, or from any gas with which it may be in contact; only this takes place with much greater rapidity in the barytic ſolution, being much more concentrated than the lime-water. Hence merely on pouring barytic water ſlowly from one veſſel to another, it becomes ſlightly turbid. The barytes as it becomes carbonated falls to the bottom as a white powder. Barytes is ſoluble in alcohol, but with difficulty unleſs aſſiſted by heat. The oxalic, citric, phoſphoric and malic acids give cryſtalline precipitates with ſaturated barytic water, which are reſoluble with a ſlight exceſs of the ſame acid. Moſt of the metallic ſolutions are decompoſed by barytic water, and the precipitated oxyds of ſilver and lead are again diſſolved by an exceſs of the barytes.[g]

Barytes, its carbonat, both native and artificial, and all its ſoluble ſalts are violently poiſonous.

The combinations of barytes with the acids are deſcribed under the reſpective acids.

The affinity of barytes with the earths very ſtrongly reſembles that of the fixed alkalies in ſeveral important particulars. The powerful action of barytes as a flux in a red heat has been already mentioned, and the eaſe with which clay crucibles are corroded by it. The two following experiments ſhew this combination very ſtrikingly.[h] Three parts of pure barytes were mixed with one of ſilex, and heated violently for an hour in a platina crucible. When taken out it was a homogeneous, porous, friable maſs, ſomewhat green, taſting ſweetiſh, and not heating when ſlaked with water, as pure barytes does. It diſſolved wholly in nitrous, muriatic and acetous acid, and gave a curdy precipitate with ammonia, whereas the ſimple ſolution of barytes is not diſturbed by this alkali. Evaporated, this ſolution ſtiffened to a jelly when nearly dry (a ſure mark of the preſence of ſilex), and when ſolid the ſiliceous earth was left in its proper character. Thus then barytes renders ſilex entirely ſoluble in acids, and potaſh does the ſame.

2. Nine parts of barytes were mixed with one of pure alumine newly precipitated from its ſolvent and ſtill wet, and the mixture was boiled for a quarter of an hour with water. This yielded both a clear liquor and an earthy reſidue. The liquor was only ſlightly burning to the taſte, and though it abſorbed carbonic acid from the air, and let fall a white barytic carbonat, it would not cryſtallize as pure barytes though the quantity of water to the earth was but ſmall. Muriatic acid, only enough to ſaturate the barytes, gave a flocculent precipitate of alumine, which an exceſs of the acid redif-

[f] Vauquelin, An. Ch. 21.

[g] Ibid. [h] Ibid. 29.

ſolved. When ſaturated with the acid, ammonia gave alſo a precipitate of alumine. The earthy reſidue from the firſt ſolution was an intimate mixture of alumine and barytes, in which the natural ſolubility of the latter in water was deſtroyed by its union with the former. Thus a great exceſs of barytes over the alumine is requiſite to a ſolution of theſe earths, which is alſo ſhewn by adding hot ſaturated barytic water to muriat of alumine: the firſt drops produce a precipitate, which a further addition of barytic water rediſſolves.

Barytes unites eaſily with all kinds of oils. If barytic water is added to a ſolution of ſoap, an inſoluble curd falls down, which is an union of the barytes with the oil of the ſoap, whilſt its alkali remains cauſtic and uncombined in the liquor. Alſo when a hot ſaturated barytic water is boiled with olive oil, a barytic ſoap is formed, differing however from the alkaline ſoaps in being inſoluble in water.

The fixed alkaline ſolutions, heated with any of the ſoft parts of animals, diſſolve them, and at the ſame time cauſe the evolution of much ammonia. Barytes has the ſame effect with regard to the production of ammonia, and forms with the animal matter a ſoft pulp inſoluble in water.

Therefore, from theſe and other ſtriking analogies, barytes (as well as ſtrontian, which agrees with it in moſt of the above particulars) has been actually claſſed as an alkali by ſome chemiſts, and by others as an *alkaline earth*.

The diſcovery of ſtrontian is of a much later date than that of barytes, and the reſemblance between the two is ſo very ſtriking in many eſſential particulars, and ſo much greater than that which ſubſiſts between any two of the other earths, that chemiſts have taken ſome pains to eſtabliſh the ſeparate identity of ſtrontian. The following are ſome of their moſt remarkable points of reſemblance.

They are both found native, only in the ſtates of ſulphat and carbonat. The ſulphats are both nearly inſoluble in water, and are formed artificially by the union of any other ſolution of theſe earths with any ſalt in which the ſulphuric acid enters. Alſo the ſulphats of theſe earths readily diſſolve in ſtrong ſulphuric acid, and are both precipitated by the addition of water. [i]

The methods above deſcribed for the decompoſition of ſulphat of barytes, apply equally to the ſulphat of ſtrontian.

The *native* carbonats are both ſcarcely calcinable by mere heat, but the artificial carbonats much more readily. They are equally decompoſed by charcoal. They alſo act with equal energy as a flux on earthy ſubſtances.

The pure earths are both cryſtallizable from their hot watery ſolutions, ſoluble in alcohol, and both exhibit in taſte and other chemical properties a very ſtrong reſemblance to the fixed alkalies, forming a ſpecies of ſoap with oils, diſſolving ſilex and alumine, and the like. They alſo attract carbonic acid from every ſurrounding body with readineſs, and in ſo doing, the earth precipitates totally from its ſolution in the form of a white carbonat.

The carbonats of each earth are ſoluble with effervescence in moſt of the acids, but the native carbonats much leſs eaſily than the artificial. Pure ammonia precipitates neither the one nor the other.

On the other hand there is ſuch a decided difference between the two earths in the following eſſential particulars, that we cannot heſitate to claſs them as diſtinct earths.

Barytes and all its ſalts (except the ſulphat which is inſoluble in moſt fluids) are violent poiſons, deſtroying animals by inflaming the ſtomach and inteſtines. The correſponding preparations of ſtrontian are quite innocent, and appear to produce no effect whatever in any moderate quantity. [k]

Strontian, or any of its ſalts diſſolved in alcohol, give to its flame a beautiful carmine red. The barytic ſalts on the other hand give only a faint yellow.

The affinity of ſtrontian to acids is leſs than that of barytes, ſo that barytes decompoſes the ſtrontian ſalts by ſimple affinity, and lime, which is weaker than barytes in its affinities, is ſuperior to ſtrontian.

The form, habititudes and ſolubility of many of the ſalts of barytes, differ from thoſe of the correſponding ſtrontian ſalts. In general the barytic ſalts are much leſs ſoluble than the ſtrontian. Barytes however is ten times more ſoluble in water than ſtrontian. [l] Sulphat of barytes is abſolutely inſoluble in water, ſulphat of ſtrontian ſlightly ſoluble, eſpecially with a ſmall exceſs of the acid, and hence the former will ſhew the preſence of ſulphuric acid in much minuter quantity than the latter. On the other hand the precipitated oxalat of ſtrontian (formed by oxalic acid and any ſolution of this earth) cannot be diſſolved by an exceſs of this acid, whereas the oxalat of barytes is ſoluble by this method. The nitrat, muriat and acetite or barytes are much leſs ſoluble in water than the correſponding ſtrontian ſalts, and are heavier

[i] Klaproth. [k] Pelletier. [l] Vauquelin.

and more opake. The little ſolubility of the nitrated barytes is ſhewn by its copious precipitation when nitric acid is added to concentrated acetited or muriated barytes, which does not take place with the ſolutions of ſtrontian. The gallic and malic acids added to barytic water give a precipitate, the former white, the latter greeniſh. With ſtrontian water no ſuch effect is produced. The muriats ſhew the moſt ſtriking difference, and hence this acid is generally reſorted to in chemical analyſis.

In a mixture of the two muriats, the barytic begins to cryſtallize in a much more dilute ſolution than the ſtrontian, and the muriated barytes forms large opake heavy oblong hexagonal tables, with ſome varieties; whereas the muriated ſtrontian does not ſeparate till the liquor is of a ſyrupy conſiſtence, and then produces long ſlender tranſparent, light, needle-ſhaped bundles of cryſtals, often radiated. This difference cannot be overlooked by the moſt careleſs obſerver.

From what has preceded, the reader will be able to underſtand the habitudes of barytes when ſubjected to chemical analyſis. The following facts may be of uſe in analyſis, in ſeparating barytes from lime and ſtrontian, the earths with which it is moſt liable to be mixed.

Pure fluoric acid, or better, fluat of ammonia, quite free from ſulphuric acid, will precipitate lime from its ſolution, but not ſtrontian nor barytes. Barytes may be ſeparated from lime and ſtrontian either by evaporating the mixed muriated ſolutions, when, as above mentioned, the muriated barytes cryſtallizes diſtinctly and ſeparately; or by judiciouſly adding cold alcohol to the entire contents of the ſolution evaporated to dryneſs, which will diſſolve out the muriats of lime and ſtrontian, and leave almoſt the whole of the muriat of barytes; or by adding ſtrong nitric acid to the concentrated ſolution, which will precipitate the nitrated barytes in cryſtals, leaving the other two earths in ſolution. The firſt of theſe methods appears the moſt exact.

It may be added that many chemiſts have been miſtaken in ſuppoſing that the Prussic acid was a teſt for barytes, for the precipitate produced by common pruſſiat of potaſh and a barytic ſolution, has been found to ariſe only from an admixture of ſulphat of potaſh with the pruſſiat.

The affinities of barytes are: in the moiſt way—the ſulphuric, oxalic, ſuccinic, fluoric, ſaccholactic, nitric, muriatic, phoſphoric, citric, tartareous, arſenic, benzoic, acetic, boracic, ſulphureous, carbonic and pruſſic acids, ſulphur and fat oil.

BASALT.[a] *Baſalt*, Werner. *Baſalte*, Brochant.

The colour of baſalt is generally greyiſh black, paſſing into aſh-grey, browniſh black and bluiſh black: the ſurfaces of its natural diviſions are of a greyiſh ochre colour, which tint is alſo acquired by the ſurface of any caſual fracture after a ſhort expoſure to the weather. It occurs in maſs or veſicular. Internally it is dull, though ſometimes feebly glimmering, on account of very minute cryſtals diſperſed through its ſubſtance. Its fracture is coarſe or fine grained uneven, or fine ſplintery; in large pieces often conchoidal, and ſometimes, though very rarely, even and earthy. It is amorphous or tabular, or in columnar angular diſtinct concretions, from a few inches to two hundred feet in length, either ſimple or articulated, and the articulations are plain, or formed by the convex end of one piece implanted in the concave end of the next; or finally it is found in globular maſſes, compoſed of concentric lamellæ of various ſizes, even to two feet or more in diameter. It is opaque, but ſometimes feebly tranſlucent on the edges. It give a light aſh-grey ſtreak: is nearly equal in hardneſs to common glaſs, but poſſeſſes a degree of toughneſs which renders it very difficult to be broken. Sp. gr. 2.86 to 2.97. It is for the moſt part attracted by the magnet, and ſometimes poſſeſſes polarity.

It melts with eaſe before the blowpipe, without addition, into a black glaſs. The baſalt of the Haſſenberg, in Bohemia, has been analyſed by Klaproth[b], and that of Staffa by Dr. Kennedy, with the following reſults.

	Klapr.	Kenn.
Silex - - - - -	44.5	48.
Alumine - - - -	16.75	16.
Oxyd of iron - - -	20.	16.
Oxyd of manganeſe -	0.12	0
Lime - - - - -	9.5	9.
Magneſia - - - -	2.25	0
Soda - - - - -	2.6	4.
Moiſture and volat. matter	2.	6.
	97.72	99.

Baſalt not unfrequently contains olivine and baſaltic hornblende, ſometimes felſpar, and when verging into Wakke, mica, calcareous ſpar, calcedony and zeolite.

According to Werner, baſalt is confined to the Floetztrap or ſecondary trapformation. It occurs in vaſt mountainous beds, moſtly of a

[a] Widenmann, Emmerling, Brochant, Jameſon, Kirwan. [b] Analyt. Eſſ. v. ii. p. 195.

conical form, in ſtrata, in banks or dykes, and in veins. It is met with in moſt parts of the world, and almoſt always accompanies coal: the columnar variety, where the pillars are long and well defined, exhibits a remarkably grand appearance. The ſmall iſland of Staffa, on the weſtern coaſt of Scotland, is entirely compoſed of baſaltic pillars, both ſtrait and bending; the Giant's cauſeway, on the coaſt of Antrim, in Ireland, is a huge pavement of ſtrait pillars, running to an unknown diſtance in the ſea, and backed by a ſteep rock, containing numerous ranges of ſimilar columns: the promontry of Fair-head, a little further to the north, exhibits a continued range about a mile in length of columns, 250 feet high, and from ten to twenty in diameter, [c] being the largeſt yet known.

The uſes of baſalt are various. From its being tougher and more durable than marble, it was a favourite material with the ancient Egyptian ſculptors, many of whoſe works executed in baſalt are at the preſent day in as perfect ſtate as when they were firſt finiſhed. The cellular variety is uſed with ſome ſucceſs as a material for millſtones. It is alſo employed as a building ſtone, a flux for certain iron ores, and as an ingredient in dark green bottle glaſs: the fine-grained is uſed as a touchſtone. Baſalt alſo when torrefied and pulverized, communicates to common mortar the property of hardening under water. [d]

The origin and formation of baſalt has long been and ſtill continues a ſubject of animated controverſy among geological philoſophers. The firſt mineralogiſts conſidered it decidedly as of volcanic origin, from its colour, its ſonorouſneſs, and the regular arrangement of its priſms. Bergman introduced the theory of its aqueous formation, from obſerving that the ſtrata which are in immediate contact with baſalt, generally exhibit appearances incompatible with the known action of fire upon them. Since the time of this great chemiſt, the two theories have nearly equally divided the mineralogical world, both with regard to numbers and abilities. The Swedes, the Germans, and the diſciples of Werner in Britain, have taken up the aqueous theory: they have ſhewn baſalt reſting upon and alternating with ſtrata of acknowledged aqueous origin, they have diſcovered ſhells and vegetable remains imbedded in its ſubſtance, they have found its cavities filled by ſiliceous nodules containing water, they have melted baſalt in their furnaces and have found it to produce a glaſs, they have ſhewn that the lava of Veſuvius and Etna differs in many important particulars from baſalt; and they have pointed out the priſmatic ſtructure in many ſubſtances, which are not ſuppoſed even by their antagoniſts to have undergone the action of fire.

The French, the Italians, and Dr. Hutton and his partizans in Britain, have for the moſt part adopted the opinion of the igneous origin of baſalt: they have ſhewn the priſmatic ſtructure of ſome undoubted Italian lavas; they have ſhewn beds of coal charred by the contact of dykes of baſalt, and the forcible diſruption, incurvation and induration of argillaceous ſtrata when pierced through by veins of this ſubſtance. Sir James Hall has proved that baſalt, after it has undergone the vitreous fuſion, may be made by ſlow cooling to aſſume a perfect ſtony appearance, and Mr. Watt's admirable experiments [e] demonſtrate that baſalt may by the medium of fire acquire thoſe peculiarities of ſtructure which are not eaſily explained on the aqueous theory, and that although deprived of its magnetic power when in the vitreous ſtate, it recovers it again as it reſumes by ſlow cooling its earthy priſmatic texture.

For further remarks on the fuſion of baſalt ſee VITRIFICATION.

BASALTINE. See HORNBLENDE.

BASALTINE, octahedral. See AUGIT.

BASANITE. See KIESELSCHIEFER.

BATH in *Chemical apparatus*. (See the Appendix.)

BAY SALT is a very pure ſalt, prepared from ſea water by ſpontaneous evaporation. See MURIAT of Soda.

BEILSTEIN. See NEPHRIT.

BELL-METAL. See COPPER, *Alloys of*.

BENZOIN *Gum*, or BENJAMIN. BENZOIC *Acid*. The gum reſin that bears the name of Benzoin or Benjamin, is brought chiefly from the Eaſt Indies, in large brittle maſſes, of unequal degree of purity and varying in colour from yellow to white. It has ſcarcely any taſte when chewed, but if previouſly diſſolved it is moderately pungent and aromatic. Its ſmell is extremely grateful when rubbed or gently warmed, this encreaſes as the heat is raiſed, and when the reſin melts, a very white and moſt fragrant vapour riſes, which is ſo pungent as to excite violent coughing, and ſoon condenſes on the ſurrounding bodies in beautiful ſhining ſaline needles. This ſalt is the *benzoic acid*.

Gum benzoin is very ſoluble in alcohol, but

[c] Nicholſon's Journ. 4to. vol. v p. 322. [d] Ann. de Chim. vol. [e] Philoſ. Tranſ. 1804, p. 279.

moſt of it ſeparates again on the addition of water. Boiling water has no other effect on benzoin than to melt it, and to diſſolve out a ſmall portion of its acid, but the reſin itſelf remains inſoluble. By diſtilling this reſin without addition it reſolves itſelf into the acid, and into a fine fragrant oil which riſe nearly together, and, by a greater heat, an empyreumatic oil is given off, and a ſpongy coal remains behind.

Benzoin is the moſt important of the claſs of *balſams* in modern chemiſtry, which are underſtood to be, reſins naturally united with that volatile cryſtallizable acid which has juſt been mentioned, and which is the ſame in all the natural balſams.

The white reſinous precipitate, which is formed by adding water to the tincture of benzoin, has been called *lac virginale*. When gently dried it is a yellowiſh white powder, ſometimes uſed as a coſmetic.

The *benzoic acid* may be prepared either by ſublimation or by digeſtion. The former method is the moſt ancient.

Put any quantity of benzoin, pure or impure, into an earthen veſſel (a common pipkin will anſwer the purpoſe) and paſte to the top of it a large cone of white paper, or join to it another pipkin inverted and fitting pretty cloſe, or in ſhort any kind of contrivance to receive and condenſe the vapour. Set the apparatus on a very gentle charcoal fire, or over a lamp, ſo that only the lower veſſel may be warmed, and heat it no more than is ſufficient to melt the reſin. The white ſuffocating fragrant vapour riſes almoſt immediately in extremely denſe fumes, and condenſes in the upper receptacle in uncommonly brilliant cluſters of ſmall needle-formed cryſtals. Continue the proceſs till nearly all is expelled at that temperature. The benzoin however ſtill retains ſome acid, which may be expelled by encreaſing the heat, but then at the ſame time ſome of the yellow fragrant oil of benzoin ariſes, which impairs the whiteneſs and purity of the acid. From nine to twelve drachms of the acid may be obtained in this way from ſixteen ounces of benzoin.

The other method of preparing this acid is that which was diſcovered by the celebrated Scheele.[a] It conſiſts in firſt heating the benzoin with lime water, whereby the acid unites with the lime, forming a benzoat of lime, ſoluble in water, and then ſeparating the benzoic acid by the muriatic, which unites with the lime by ſuperior affinity. Some management however is requiſite to prevent the benzoin from running together when melted by the heat of the boiling water, and ſwimming at the top in a maſs impenetrable by the liquor. Scheele adviſes the following: pour 12 ounces of water upon 4 ounces of well burnt lime, and when ſlacked add 6 pounds more of water. Then put a pound of finely powdered benzoin into a tin pan, with 6 ounces of the above lime-water, mix them well together, after which add the reſt of the lime-water. The benzoin will thus be prevented from running together. Boil for half an hour with conſtant ſtirring, and ſtrain the liquor through a cloth. Repeat the boiling with freſh lime-water, and ſtrain as before, preſſing the reſidue to extract all the liquor. This is now a very weak ſolution of benzoat of lime, the benzoic acid having united with the lime contained in the lime-water. Boil down this liquor (which is a light yellow) to two pounds, and ſtrain. When cold add muriatic acid, as long as any white precipitate falls down, and till the ſolution taſtes ſenſibly ſour. After ſtanding ſome hours, collect the precipitate and ſlightly rinſe it with cold water. It is now pure benzoic acid. The reaſon of its precipitation is its very ſparing ſolubility in cold water when no longer united with lime. Boiling water diſſolves $\frac{1}{20}$ of its weight of benzoic acid, but cold water only $\frac{1}{400}$, and hence almoſt all the contents of a hot ſaturated ſolution are depoſited on cooling. More benzoic acid is procured by the intermede of lime than by ſimple ſublimation. Scheele obtained in this way from 12 to 14 drams from 16 ounces.

Cream of lime, or ſlacked lime ſuſpended in water to the thickneſs of cream, will anſwer as well as clear lime-water, and a leſs bulk of liquid will thus ſuffice, which will ſhorten the evaporation. The acid procured in this way is in the form of a granular powder. It may be made into ſpicular cryſtals by rediſſolving in boiling water and cooling. Almoſt any acid will ſeparate the acid from the benzoat of lime, but the muriatic is the moſt convenient. The ſulphuric is not ſo proper, as the ſulphat of lime when produced will partly fall to the bottom and mix with the benzoic acid.

A ſmall quantity of the acid may be extracted from gum benzoin, merely by boiling in water, which cryſtallizes as the water cools, but with the inconvenience above mentioned, of the reſin melting together in a maſs, which ſwims at top, and prevents the water from penetrating it.

Cryſtallized benzoic acid, particularly that obtained by ſublimation, is remarkably light,

[a] Eſſays.

feathery and elaſtic. When pure it is quite white, for the yellowneſs is owing to the admixture of oil. But as it retains its fragrant ſmell through ſucceſſive cryſtallizations and ſolutions, it is probable that a portion of oil remains in very cloſe union with it, and hence perhaps the extreme weakneſs of its affinity with earthy and alkaline baſes.

In ſolution with water the taſte of the acid is ſharp, ſouriſh and pungent, and it reddens litmus. Heated without addition a part ſublimes unaltered, but the reſt is decompoſed into the uſual products of vegetable matter. Thrown on hot coals it burns readily with a moſt pungent ſmoke.

Benzoic acid is alſo contained in ſtyrax and balſam of Tolu, giving them the characters of true balſams according to the modern ſyſtem; and it is met with more ſparingly in ſeveral of the fragrant barks, reſins and other vegetable matters. It generally appears in its proper character when theſe ſubſtances are gently heated, or it may be extracted with lime in the way above mentioned.

Benzoats. Theſe are too little known to require ſeparate deſcription. The benzoic acid unites with all the alkalies and moſt of the earths, forming generally ſoluble ſalts, from all of which the acid may be ſeparated by the muriatic, as above deſcribed, from the benzoat of lime. Many of the metallic oxyds are ſoluble in this acid, but not the metals themſelves. The *benzoat of lime* has been diſcovered by Fourcroy in the urine of the horſe, and ſome other herbivorous quadrupeds. It appears to be the cauſe of the ſub-aromatic ſmell ſometimes perceived when theſe animals ſtale.

The affinities of this acid appear to be in the following order: lime, barytes, magneſia, potaſh, ſoda, ammonia, alumine and metallic oxyds.

BERGHOLZ. See Asbest.

BERGKORK. See Asbest.

BERGKRISTAL. See Quartz.

BERGMILCH. Agaric mineral.

The colour of this mineral is yellowiſh-white, approaching to ſnow-white and greyiſh-white: it is compoſed of ſlightly-cohering very fine particles; it is dull, opake, has a meagre feel, ſoils the fingers when handled, and is ſo light as nearly to float on water.

It effervesces ſtrongly, and is entirely diſſolved in acids. It has not been formally analyſed, but appears to be a pure or nearly pure carbonat of lime.

It is found in fiſſures and holes of ſecondary limeſtone in Switzerland, and at Sunderland in the county of Durham. It is not made any uſe of.

BERGSEIFE.[a] Mountain ſoap.

This mineral was firſt deſcribed by Werner. Its colour is browniſh black, paſſing into ſmoak-grey: it is found in maſs and diſſeminated: internally it is dull: its fracture is fine-earthy, paſſing into flat conchoidal. It is opake, does not ſtain the fingers, gives a ſhining reſinous ſtreak, is very ſoft, adheres powerfully to the tongue, and is light.

It has not been analyſed; and bears a conſiderable reſemblance to indurated lithomarge.

It is found in rocks belonging to the ſecondary trap-formation, and is very rare: the only places where it has yet been diſcovered are, Otkuſch in Poland, in Bohemia, where it is uſed for waſhing linen, and in the iſle of Skye in Scotland.[b]

BERNSTEIN. See Amber.

BERYL. See Emerald.

BEZOARD *Mineral* is a perfect oxyd of Antimony, made by digeſting in nitric acid the precipitate from butter of antimony by water.

BILDSTEIN.[c] Agalmatolite of Klaproth. Talc glaphique, Hauy.

There are two varieties of this mineral, the ſemitranſparent and the opake.

Var. 1. *Semitranſparent.* Its colour is olive and aſparagus green, paſſing into greeniſh grey: internally it is ſhining and has a greaſy luſtre: its parallel fracture is obſcurely ſlaty, its croſs fracture is ſmall ſplintery, paſſing to compact uneven: it is tranſlucid paſſing to ſemitranſparent, is ſoft, and has a greaſy feel. Sp. gr. 2.81.

It has been analyſed by Klaproth, and appears to contain

54.	ſilex,
36.	alumine,
0.75	oxyd of iron,
5.5	water.
96.25	
3.75	loſs
100.00	

Var. 2. *Opaque.* This differs from the preceding in the following particulars. Its colour is reddiſh-white paſſing into fleſh-red and variegated with different coloured veins: it poſſeſſes little or no luſtre, and has a compact fracture:

[a] Widemann, p. 436. [b] Jameſon's Mineralog. p. 396. [c] Hauy, Emmerling, Klaproth Analyt. Eſſ. v. i. p. 465.

it is opake or at moſt tranſlucid on the edges. Sp. gr. 2.78.

It is compoſed, according to Klaproth, of

.62	ſilex,
.24	alumine,
1.	lime,
0.5	oxyd of iron,
10.	water.
97.5	
2.5	loſs
100.0	

The bildſtein comes from China, and is the ſubſtance of which the little Chineſe ornaments and figures for chimney-pieces are made. It has uſually been conſidered as a variety of ſteatite; but from the total abſence of magneſia in its compoſition, and its external characters, appears to be nearly related to lithomarge.

BILE. *Galle*, Germ.

This moſt important animal fluid is ſecreted in all animals by the liver, and is generally one of the moſt abundant of all the animal ſecretions. Some are alſo furniſhed with a reſervoir or bag, ſubſidiary to the liver, and called the gall-bladder. The uſe of this organ is foreign to the preſent ſubject, but its exiſtence gives riſe to ſome diſtinction between the bile of the liver and that of the gall-bladder, the *hepatic* or *cyſtic* bile.

All the experiments undertaken in a large way have been upon the *cyſtic* bile, or that of the gall-bladder, on account of the eaſe with which this is procured after death, whereas that of the liver can only be obtained with difficulty and in very ſmall quantity. It does not appear however that any material difference exiſts between the two, except that the cyſtic is ſomewhat thicker than the hepatic; nor have any ſatisfactory experiments been made to determine whether the kind of food taken in, or the ſpecies of animal, cauſes any alteration in the quality of bile. That of the ox, commonly called *ox-gall*, has uſually been ſelected, though the deſcription of its chemical properties will without doubt apply with very little variation to every ſpecies of bile.

Bile is a yellowiſh-green fluid, viſcous and tenacious like white of egg diluted, and of a denſity greater than that of water. The ſpecific gravity is given ſo differently by various writers that it certainly varies conſiderably, according to the age, food, health, &c. of the animal. It may be ſaid to be from 1.02 to 1.04. The ſmell of recent bile is peculiar and often ſub-aromatic, but this changes to a very peculiar fœtor when putrid. To the taſte it is intenſely bitter (ſo much as to be proverbial) and ſub-ſaline: it froths violently when beaten up, and mixes with water, though ſlowly, in any proportion. It ſhews ſtrong marks of a predominant alkali, by changing blue vegetable colours to green, and, as will preſently be ſeen, it actually contains ſoda in excefs, but not carbonated.

Bile gently heated does not coagulate, but loſes the greater part of its water, and by keeping the temperature within the boiling point of water and long evaporation, it loſes nearly ſeven-ninths of its weight [a] of an inſipid liquid, differing in nothing from pure water, except by having a faint unpleaſant ſmell.

The reſidue when cold becomes dry, brittle, of a dark brown, intenſely bitter, but at the ſame time ſomewhat ſweetiſh, and very inflammable. When expoſed to air it deliqueſces and reſolves itſelf into a thick pitchy maſs. It alſo readily ſoftens by the heat of the hand, and melts over the fire. It may be now preſerved a very long time without putrefying, but bile itſelf begins to be very fetid and ſomewhat putrid in a few days in ſummer, though later than moſt of the animal juices. In this ſtate a ſmell of muſk is alſo very perceptible.

The thick *extract* or *inſpiſſated bile* when heated in a retort without addition, gives out firſt a watery liquid containing ſome ſulphuretted hydrogen, [b] whilſt the bile in the retort puffs up to a prodigious bulk. A red liquor follows, which contains an empyreumatic oil, at firſt clear and not ungrateful, but afterwards foul and extremely fetid. Some carbonat of ammonia riſes, but in remarkably leſs quantity than is yielded from moſt animal ſubſtances of ſimilar conſiſtence. [c] Carbonic acid, carburetted hydrogen, and other gaſſes follow in great abundance. A black ſpongy coal is left, which is deliqueſcent in the air, and after ſome days ſhews a ſaline efflorescence of carbonat of ſoda. This alkali is alſo left in the aſhes of the coal when thoroughly burnt in the open air. The analyſis by fire alone does not throw much light on the compoſition, any further than to ſhew the preſence of uncombined ſoda, which remains in the aſhes after every thing elſe has been expelled. It is by other means that the nature of bile is more fully detected.

The extract of bile inſpiſſated by *gentle* heat,

[a] Van Bochante. Jour. de Phy. tom. 15. [b] Fourcroy, Syſt. de Conn. Chim. [c] Van Bochante.

though it has ſome of the appearance of a reſin and burns like one, is ſtill readily again ſoluble in water, and appears thereby to return nearly to the ſtate of unprepared bile.

Alcohol and acids are the moſt valuable reagents for diſcovering the true nature of bile.

If dilute muriatic acid (and any other will anſwer the purpoſe) is added to bile, a greeniſh coagulum is immediately formed, which when collected is very tenacious, and intenſely bitter. The clear liquor ſtill remains bitter as well as ſour, but if the acid and the bile are boiled together[d] the ſeparation is more perfect, the liquor is now ſcarcely bitter, and has little other taſte beſides that of the acid added, whilſt the whole of the ſapid and colouring matter of bile has gone into the precipitate, which is now intenſely bitter, of a dark green and tenacious, and may be dried into a brittle reſin-like maſs. This however is different from ſimply inſpiſſated bile in being deprived of the ſoda which is natural to this fluid, and this alkali is now found, on evaporating the clear liquid, united to the muriatic acid, and cryſtallizes in ſmall cubes when the evaporation is carried nearly to dryneſs. If ſulphuric acid has been uſed to decompoſe the freſh bile, the ſalt is ſulphat of ſoda, if the nitric acid, nitrat of ſoda,[e] and by this moſt ſatisfactory experiment the preſence of the naked alkali is fully demonſtrated. No ſenſible quantity of muriatic acid in any form appears to exiſt in bile, as it ſhews no precipitate with nitrated ſilver.

The dark green bitter coagulum ſeparated by the acid is found to conſiſt of at leaſt two ſubſtances, one, an animal matter reſembling albumen in moſt of its properties, the other a peculiar reſinous matter, in which reſides the colour and bitterneſs of bile, and which was before held in ſolution as a kind of ſoap with the ſoda, which afterwards quitted it to join the acid. Acids therefore act here in a double capacity, they precipitate the albumen, as they always do whenever they come in contact with it, and they alſo precipitate the reſinous matter by detaching it from its union with the ſoda, which makes it ſoluble in natural bile. The biliary reſin and ſoda appear to form a pretty cloſe union with the albumen in recent bile, for when this liquid is heated to boiling, none of the albumen viſibly coagulates, and the bile remains as clear as ever, which could not take place unleſs the albumen were prevented from coagulating by ſome intimate union with a ſubſtance uncoagulable by mere heat. Even when white of eggs is previouſly mixed with the freſh bile and heated to boiling, no coagulation takes place, ſo that the biliary reſinous ſoap is able to prevent this ſeparation in a much greater quantity of albumen than is natural to the bile.

The precipitate formed by acids has been mentioned to conſiſt of albumen and a ſubſtance which may be called *biliary reſin*. Theſe are entirely ſeparable by alcohol, which only diſſolves the reſin, forming a dark brown bitter tincture, whilſt the albumen remains behind. This tincture, though it reſembles the tincture of ſimply inſpiſſated bile in colour, taſte and inflammability, differs from it in ſome material points. The latter (as it retains its ſoda and albumen) is uniformly miſcible with water, and is in appearance much more like a ſoapy tincture; the former cloſely reſembles the tinctures of the vegetable reſins, and on the addition of water becomes inſtantly turbid and parts with nearly all that it had diſſolved, which ſubſides as a dark pulverulent maſs not ſoluble in water.

Alcohol added to bile gives an immediate coagulum, which is nearly white, and when waſhed in water, in which it is now inſoluble, it retains ſcarcely any bitterneſs, burns on coals like horn, and is nearly pure albumen. The liquor from which it has ſeparated is green and bitter, and contains both the biliary reſin and the ſoda. Evaporated to dryneſs it leaves a fine reſinous ſoap, which on account of the ſoda remains equally again ſoluble in water as in ſpirit. If the bile is firſt inſpiſſated, and the alcohol then applied, it diſſolves out of the thick extract only the reſin and ſoda, leaving the albumen. This latter ſolution is itſelf decompoſed by acids, which, uniting with the ſoda, precipitate the biliary reſin pure.

The alkalies render bile more fluid, but produce no remarkable change. When concentrated they diſengage a little ammonia. Barytic, ſtrontian, and lime-water added in large quantity unite with the reſin, and form an inſoluble ſoapy precipitate.

The metallic ſalts decompoſe, and are decompoſed by bile, forming precipitates conſiſting chiefly of albumen, and of the metallic oxyd united with the biliary reſin.

Some phoſphoric ſalts are alſo to be found in bile, though in ſmall quantity.

The reſin of the bile, though reſembling the vegetable reſins in ſolubility in alcohol, inſolubility in water, brittleneſs, inflammability, &c. has ſome properties which ſhew it to be of a peculiar nature.

[d] Saunders on the Liver. [e] Cadet.

Fourcroy has further examined this curious ſubſtance. On paſſing the oxymuriatic acid gas through freſh bile diluted with a little water, the firſt effect is to coagulate the albumen, which is depoſited in white flocculi. At the ſame time both the ſmell and colour of the bile entirely diſappear, but the intenſe bitterneſs remains. On continuing the proceſs, the greater part of the reſin ſeparates in the form of a white, unctuous, concrete maſs. Any other acid produces the ſame precipitate, if added after the bile has abſorbed ſo much of the oxymuriatic acid as to loſe its colour. This white concrete ſubſtance differs conſiderably from the reſinous precipitate formed by the ſimple muriatic or other acid, and rather reſembles *adipocire*, for it is ſoluble eaſily in hot water (which the reſin is not) and alſo in alcohol, which liquor during the ſolution paſſes nearly to the ſtate of ether. This alcoholic ſolution is alſo miſcible with water (in which it differs from the reſin), and is again ſeparable thence by muriatic acid. It more reſembles the foliated ſubſtance contained in *Biliary Calculi*. Theſe curious experiments deſerve repetition.

It is uncertain whether that which gives colour and odour to the bile is a ſeparate principle, or whether it reſides in the reſin.

Some chemiſts have imagined a ſaccharine matter in bile to be indicated by the ſweetiſh taſte of the inſpiſſated extract, and the tendency to vinous fermentation which it aſſumes by keeping, but its exiſtence is by no means clear.

Bile putrifies with difficulty, for though it ſoon acquires a very naufeous ſmell by keeping, the putrefaction advances very ſlowly and imperfectly. If it is boiled a few minutes in this ſtate it becomes very green, and is long preſerved from further alteration. When thickened by evaporation to a ſyrupy conſiſtence, it will remain freſh for many months, during which it aſſumes ſomewhat of a vinous ſmell. In any caſe the bitterneſs remains apparently unaltered.

Bile has been occaſionally employed with advantage in medicine, when diſſolved in alcohol or inſpiſſated. But its chief uſe out of the body is a detergent to ſcour wool and cloth, remove greaſe, ſpots, &c. Ox-gall is chiefly turned to this purpoſe. It here ſeems to act as a kind of ſoap, but with ſuperior powers as a detergent, than the mere quantity of alkali in it would indicate.

The ſame property of mixing with and diſſolving oily matters renders bile uſeful to painters in various ways. Ivory when rubbed with ox-gall loſes its greaſy gloſs, and is thereby much fitter to receive colours, and the gall itſelf is uſed to mix greens, biſtre, and ſome colours where the greeniſh yellow of the gall is not perceived. As no animal has been found deſtitute of bile, it appears a moſt eſſential fluid to the animal economy.

BILIARY CALCULI. Hard concrete roundiſh ſubſtances are often found in the gall bladder, or more particularly in the ducts from the liver and the gall-bladder to the inteſtine, or ſometimes paſſed on into the bowel itſelf, and which during life are often the cauſe of a moſt painful diſeaſe. Theſe concretions have attracted the notice of chemiſts.

Biliary calculi (or *gall-ſtones* as they are alſo termed) vary much in external appearance as well as chemical properties, though there is upon the whole more ſimilarity between theſe than between urinary calculi. The colour is generally green or yelloviſh brown, ſometimes white; in ſhape they are often oblong, ſometimes tuberculated. When cut through they moſt frequently conſiſt of a radiated ſemi-cryſtalline maſs, internally often reſembling ſpermaceti, coated with ſeveral concentric laminæ.[a] The radiated part is moſtly white and then taſteleſs, the laminated is ſometimes bitter.

Gall-ſtones are diſtinguiſhed for their lightneſs and inflammability, few of them being ſo heavy as to ſink in water, and when put to a lighted candle they generally melt like wax and kindle with a bright flame, attended with very little ammoniacal ſmell. From the infinite minute varieties in gall-ſtones no natural arrangement is indicated, but the moſt important indications for analyſis are the proportion of the cryſtallized radiated part, and the general lightneſs and inflammability.

Gall-ſtones are uſually largely ſoluble in oil of turpentine, and in all the eſſential oils by heat. Alcohol when cold has but little action, but when boiled it diſſolves almoſt all the inflammable part, leaving an earthy reſidue behind. On cooling, this ſolution depoſits very copious ſpicular cryſtals, ſtrongly reſembling thoſe of ſpermaceti treated in the ſame way, and this ſingular ſubſtance forms by far the moſt curious part of the compoſition of theſe concretions. Pouletier and Fourcroy[b] have both attended minutely to this ſubſtance. The former diſcovered ſimilar cryſtalline concretions in a piece of liver long expoſed to the air.

When the hot alcoholic ſolution of this concrete is dropped into a large quantity of water,

[a] Baillie Morbid Anat.

[b] An. Chim. tom. 3.

a white flocculent precipitate is formed, which when dried is found to be of a resinous nature. The supernatant liquor, by saturation with muriatic acid and evaporation, gives muriat of *soda*,[c] by which it is evident that this alkali remains in union with the biliary resin after it has undergone the change (as yet not quite understood) into biliary calculus.

Ether and oil of turpentine dissolve the spermaceti-like concrete, and deposit the greater part in crystals on cooling. Hot nitric acid acts upon it readily with disengagement of nitrous gas. When cool, a white oil concretes on the surface of the acid, now no longer of a crystalline texture, and altered in its properties, being brittle and friable like a resin, and when redissolved in alcohol it does not again crystallize on cooling.[d] It is still insoluble in water. Ether dissolves this altered concrete as it did in its natural state, but water again separates it in the form of *drops of oil*.

These singular anomalies shew that the radiated crystalline part of biliary calculi is considerably different from spermaceti or adipocire, and to the physiologist the subject is worth pursuing.

BIMSTEIN. See PUMICE.

BIRDLIME is a very singular kind of tenacious cement prepared from the bark of some trees, particularly the holly, and also from the misletoe. The holly bark is first boiled for ten or twelve hours, which separates the green outer coat from the inner, it is then covered up for a fortnight in a moist place, and afterwards pounded into an uniform paste, washed in water, fermented for four or five days, and laid up for use. When used, it is incorporated with a third of its weight of nut oil. Many other vegetables yield by maceration a similar stringy tenacious juice, insoluble in water and miscible with oils.

BISMUTH. *Wismuth*, Germ.

Bismuth is a metal of a very dilute yellowish and reddish white colour; it is brittle, has a lamellar texture, and is divisible, parallel to the sides of a regular octahedron, is more fusible than lead, and is readily soluble in nitrous acid, from which it is almost entirely precipitable in the form of a white powder, by the addition of water.

The ores of bismuth are comparatively of rare occurrence, and are arranged by mineralogists under the three following species.[e]

I. Native Bismuth. *Gediegen Wismuth. Bismuth natif.* Hauy and Brochant.

The colour of this substance is silvery-white, verging more or less upon red; it is often iridescent on the surface. It occurs disseminated, or superficial, feather-shaped reticular or cellular, rarely in mass and very rarely crystallized. Its forms are very small quadrilateral tables and cubes. It possesses both externally and internally a brilliant metallic lustre. Its fracture is lamellar or broad radiated, and generally exhibits granular distinct concretions. It is soft, and in some degree ductile. Sp. gr. 9.57.[f] It fuses very easily, and is entirely dissipated before the blowpipe in a yellowish white smoak. It has not been regularly analysed, but often contains besides bismuth a very small portion of arsenic and cobalt, hence when melted it exhales a slight alliaceous odour.

It is found in the veins of primitive mountains in a gangue of quartz, calcareous spar or heavy spar, indurated clay or jasper, accompanied by cobalt, kupfernickel, and occasionally by native silver, blende and galena. It is met with in Bohemia, Saxony, Transilvania, Sweden and Brittany.

II. Sulphuretted Bismuth. *Wismuth glanz. Galene de Bismuth. Bismuth sulfuré*, Hauy.

Its colour is between tin-white and lead-grey, the surface being often yellow or iridescent. It occurs in mass or disseminated, or more rarely in small lamellæ or acicular crystals implanted in each other. Its fracture is generally radiated, sometimes lamellar. Its lustre is brilliant metallic. It generally stains the fingers, and gives an obscurely metallic streak. Sp. gr. 6.13.

It melts easily and gives out a sulphureous odour and blue flame, but is with difficulty freed from the whole of the sulphur. According to the analysis of Sage and La Peyrouse it contains about 60 per cent. of bismuth, 36 of sulphur and a little iron. It is distinguishable from galena by its superior fusibility, and by not breaking into cubical fragments, and from sulphuret of antimony by being somewhat less fusible, and by not being entirely evaporated before the blowpipe.

This mineral is extremely rare, it has been found accompanying native bismuth in Bohemia, Saxony and Sweden.

A variety of this ore with a more than usual silvery appearance is described by Born as a molybdic silver, *wasserbley silber*; it has however been lately analysed by Klaproth, and contains 75 per cent of bismuth and 5 of sulphur.

[c] Saunders. [d] Bostock, Phil. Journ. vol. 6. p. 136.
[e] Kirwan, Brochant, Hauy, Emmerling, Widenmann. [f] Kirwan.

III. Biſmuth ochre. *Wiſmuth okker. Biſmuth oxyde*, Hauy.

Its colour is yellowiſh grey paſſing into aſh-grey, greeniſh grey or ſtraw-yellow. It occurs very rarely in maſs, but more commonly diſſeminated or inveſting the ſurface of other minerals. Internally it poſſeſſes a common ſhining luſtre. Its fracture is fine-grained uneven or earthy. It is tender, often friable: and is heavy, but its exact ſpecific gravity has not yet been aſcertained.

It is ſoluble in nitrous acid *without* effervescence according to Kirwan, but *with* effervescence according to Brochant, and before the blowpipe on charcoal is eaſily reduced to a metallic globule. It appears to be a pure oxyd of biſmuth, occaſionally combined with carbonic acid.

Biſmuth ochre is very rare, and is found principally at Schneeberg in Saxony, accompanying native biſmuth.

The reduction of the ores of biſmuth is very eaſy on account of its ready fuſibility and the ſlightneſs of its affinity with ſulphur. The native and oxidated biſmuth are worked in the great way ſimply by heating the ore in contact with burning fuel. For this purpoſe ſome dig a ſhallow hole in the ground, fill it looſely with wood and buſhes, and when the fire is kindled throw upon it the ore broken in pieces. Others fill the hollow of the ſtump of a pine tree alternately with wood and with the ore, and ſet it on fire. In either caſe the biſmuth melts out from its matrix, and is found in a maſs at the bottom. For the nicer purpoſe of aſſay more exactneſs is requiſite.

The native and the oxidated biſmuth are thus reduced: mix them with their weight of black flux, put into a crucible, cover with ſalt to about a fingers' breadth, and melt for five minutes with a pretty briſk fire. When cold, the biſmuth is found in a clean button beneath the ſcoria. Gellert[g] uſes one part of borax and the ſame of powdered glaſs to two of the ore, and fuſes in a crucible lined with charcoal, which is perhaps ſtill more exact; but where the oxyd is uſed it ſhould alſo be mixed with a little oil, roſin or charcoal.

The ſulphuret ſhould firſt be roaſted for a moderate time to expel moſt of the ſulphur, which is not difficult to drive off, and then mixed with black flux and treated as the former. In this manner Sage obtained 60 of metal from 100 of the roaſted oxyd.[h] No great intenſity of heat is required in theſe reductions. The metal thus obtained is not however pure, as it retains any lead, ſilver and other metals with which it may be naturally combined. The quantity of ſilver may afterwards be known by working off a determinate weight of the biſmuth on a cupel in the manner of lead, as deſcribed in the article Assay. When the proceſs is finiſhed, the oxyd of biſmuth will be entirely abſorbed by the cupel, and with it all the baſe metals, and the ſilver alone will remain in the metallic ſtate. To determine the exact proportions of the other metals, recourſe muſt be had to the humid way of aſſaying. No previous roaſting is here requiſite. The nitrous acid diluted with no more than a third of water is the beſt menſtruum. The native or ſimply oxidated metal diſſolves readily in this acid in the cold or only with a gentle heat; the ſulphuret requires boiling, whereby the ſulphur is precipitated and the biſmuth diſſolved. It is a ſtriking property of the nitrat of biſmuth to let fall almoſt the whole of the metal in the ſtate of a fine white oxyd when drenched with water. Hence by far the greater part may be ſeparated from lead, iron, copper, ſilver and cobalt, with which it is more commonly alloyed, by this ſimple method; the nitrats of theſe other metals not being decompoſed by large dilution. To ſeparate the biſmuth totally, let the clear liquor remaining over the precipitated oxyd be evaporated to a very ſmall bulk, ſo as juſt to hold in ſolution the nitrated metals, or if part of the nitrated lead cryſtallizes (which it will do the ſooneſt of the above nitrats) dilute again with juſt water enough to rediſſolve it. Then add muriatic acid by drops[i] as long as any white cloud appears. This ſecond precipitate conſiſts of the remaining portion of oxyd of biſmuth mixed with the muriat of ſilver, if this metal was contained in the ſolution. Add a few drops of ſtrong nitric acid to this, which will diſſolve the biſmuth and leave the ſilver, and again drench this ſecond portion of nitrated biſmuth with water, which will now ſeparate the whole. Hence the obſtacle to the total precipitation of the biſmuth in the firſt inſtance appears to be the great dilution, for the remaining portion is obtained by again making a concentrated ſolution. It may be worth obſerving that as the muriat of ſilver very ſpeedily turns of a ſlate colour when expoſed to light, this trial ſhould at firſt be made with the precipitate by muriatic acid, and if the pure full white is not altered, it is a proof that no ſilver is contained, and the white precipitate may then be ſet down as oxyd

[g] Chimie Docimaſt. [h] Mem. de l'Acad. 1782. [i] Klaproth.

of bismuth and added to the first quantity. According to Klaproth 100 grains of metallic bismuth make 123 grains of the white oxyd, whence this oxyd is composed of 81.3 per cent. of bismuth and 18.7 of oxygen. The bismuth and silver being thus disposed of, the nitrated solution now contains chiefly lead, with perhaps some iron, copper and cobalt, which are obtained separate in the way described under these respective metals.

Bismuth when pure is a white metal with a little tint of red, so brittle as to be readily reducible to powder, very brilliant in its fracture, and with a disposition to the octahedral form. Its specific gravity is 9.822. It does not readily tarnish, except exposed to any sulphureous vapours, but when long exposed to air assumes a pale violet colour. It is extremely fusible, melting at about 460°, that is, long before it is red hot. When heated very intensely in close vessels it sublimes unaltered and crystallized in plates.

Bismuth is of all the metals the most easy to crystallize artificially, and this experiment is highly beautiful. A quantity of it (the more the better) melted in a crucible, slowly cooled till the surface and sides begin to solidify, and then inverted so as to pour out the middle, which is yet fluid, will seldom fail to exhibit in the hollow left by the fluid metal, very fine cubic crystals of considerable size. Or better in the following way: bore a large hole through the bottom of a crucible and plug it up with a piece of iron, fill this crucible with bismuth, inclose it in another with sand interposed, and heat the whole red hot, covering the inner crucible. Remove both together from the fire, and let the metal cool gradually till it is crusted over at top, then lift the inner crucible out of the sand, draw out the iron plug (which will require pretty strong pincers) and allow the still fluid metal to flow through the hole. If well managed, and if some pounds of bismuth be used, remarkably beautiful crystals will thus be produced.

Bismuth also crystallizes in very perfect cubes from its solution in Mercury. A singularly fluid amalgam is produced by mixing equal parts of amalgam of bismuth with amalgam of lead (each composed of equal parts of mercury and the other metal), and from this, which is nearly as fluid as running mercury, the bismuth crystallizes by repose.

When bismuth is kept at a low red heat with full access of air, the surface is gradually converted into a dull grey oxyd. By skimming it off and exposing fresh surfaces, the whole is thus changed. A hundred parts of the metal were repeatedly found by Geoffroy [k] to acquire 10 parts in weight by this process, so that 100 parts of this oxyd would consist of 90.9 of metal and 9.1 of oxygen. With a moderately strong fire this melts into a greenish yellow glass. If bismuth is very strongly heated, as on the blowpipe, especially with oxygen gas, or thrown into a crucible white-hot, it takes fire and burns with a bluish flame and a dense smoke, which quickly settles on the surrounding cooler bodies in the form of a yellowish powdery oxyd. This deflagration is remarkable when bismuth is used with silver in assaying, instead of lead, and the heat is raised too suddenly: it then suddenly spirts out on every side globules, which burn with a very brilliant flame within the muffle. Bismuth also burns very well with a whitish blue flame when thrown, finely powdered, into a flask of oxymuriatic acid gas. The oxyd of bismuth by heat may be prepared with a proper subliming vessel, allowing a sufficient current of air upon the strongly heated metal. This sublimed oxyd is no further volatilizable by any heat, but readily melts (like the grey oxyd) into a yellowish green glass. When melting it acts a little on the crucible, but not nearly with the same energy as the vitreous oxyd of lead. It does not give a glass of much body of colour when fused with vitrescent mixtures. It does not appear quite certain from any accurate experiments whether there exists more than one state of simple oxidation of bismuth by heat, but as Geoffroy estimates an increase of 10 in 100 of metal by calcination, it is probable that the oxyd when fused does not contain more than this proportion, and would therefore be composed of 90.9 of metal and 9.1 of oxygen; whilst the oxyd by nitrous acid, according to Klaproth, consists of 81.3 of bismuth and 18.7 of oxygen. The sublimed oxyd or *flowers* perhaps approaches more to the latter state of oxygenation.

The sulphuric acid has no action on bismuth in the cold, in whatever state of concentration, but at a boiling heat the strong acid partly dissolves, and partly oxidates the metal, giving out sulphureous acid gas and some sulphur. If the acid be distilled off nearly to dryness, on cooling there are found lying on the oxyd a number of small feathery crystals of sulphat of bismuth. A small addition of hot water dissolves out these crystals, which are again mostly deposited on

[k] Mem. de l'Acad. 1753.

cooling. A large quantity of cold water decompoſes the ſulphat as well as the nitrat, and gives a copious white precipitate.

The action of the nitric acid on biſmuth has been mentioned in the analyſis. It is extremely vehement when the acid is at all concentrated, and attended with a copious emiſſion of red nitrous vapour. The ſtrong acid only oxidates the biſmuth, a ſmall dilution is requiſite to hold much of it in ſolution. The nitrat cryſtallizes by ſlow evaporation.

The oxyd precipitated from the nitrat by water has long been uſed as a coſmetic on account of its exquiſite whiteneſs, but much care is required to give the preparation its moſt ſaleable excellence. It is the baſis of the *Fard* or *blanc de Fard*. The chief precautions requiſite appear to be the purity of the water, and great perſeverance in waſhing and edulcorating the precipitate Artiſts diſtinguiſh two ſorts of biſmuth-white; the *blanc de fard*, which is a fine powder of a pure dead white; and the *blanc de perle*, which has a very beautiful gliſtening appearance very like the luſtre of pearls. The exact way of preparing this laſt is kept a ſecret, but it is probably made by uſing the muriatic acid much diluted as the precipitant inſtead of pure water, for a brilliant pearly white is given by this method. Some employ the nitro-muriatic acid, carefully freed from all admixture of the ſulphuric, as the ſolvent for the biſmuth. [1]

Muriatic acid acts on biſmuth only when hot and highly concentrated. A fetid hydrogenous gas is given out during the ſolution. The oxyd is more ſoluble. Muriat of biſmuth cryſtallizes in long needles: it is decompoſed by much water, as well as the nitrat. This ſalt when evaporated to dryneſs and diſtilled *per ſe*, gives a thick ſublimed *butter*, which is eaſily fuſible at a gentle heat, and almoſt totally decompoſable by water.

If the oxyd of biſmuth is rubbed with muriated ammonia, a ſmell of volatile alkali is immediately perceivable, and by heat all the ammonia is expelled, and a muriat of biſmuth remains which readily ſublimes by heat.

The oxygenized muriatic acid diſſolves biſmuth or its oxyd very readily. In the gas the metal burns with a blue flame, as already mentioned. The ſalt remaining after the action of this acid is the *butter*, by ſome termed the *oxymuriat of biſmuth*, but the preciſe action of this acid, and the difference between the cryſtallized muriat and the butter are not exactly known. The butter is alſo produced by diſtilling equal parts of biſmuth and corroſive mercurial muriat.

The phoſphoric acid acts but little on biſmuth, but diſſolves its oxyd without difficulty into a white ſaline maſs very little ſoluble in water. By heat this melts into an opake white glaſs.

Acetous acid diſſolves the oxyd though with difficulty and only in ſmall quantity. This ſolution is not precipitated by water.

Many of the other acids diſſolve the oxyd of biſmuth, but with no appearance worth remarking.

In general it may be obſerved that the ſolutions of this metal do not give a *ſaline* precipitate with the ſulphuric and ſome other acids, as the ſolutions of lead and ſome of the other white metals do, and when any precipitate is formed it is merely the oxyd. Hence theſe acids decompoſe the ſolution, probably merely on account of the water with which they are mixed. Thus *dilute* muriatic and *dilute* ſulphuric acid precipitate only a white oxyd of biſmuth from the nitrous ſolution, and not a muriated or ſulphated oxyd, as would happen with the nitrats of lead, ſilver, &c. and the *concentrated* acids give no precipitated oxyd at all. This circumſtance is of great uſe in analyſis, in ſeparating biſmuth from other metals. All the ſalts of biſmuth when in ſolution have an exceſs of acid.

The carbonated alkalies precipitate from all the acid ſolutions of biſmuth a white carbonated oxyd of biſmuth.

Neither the fixed nor the volatile alkalies act upon biſmuth, but in ſome degree upon the white oxyd. This latter boiled with cauſtic potaſh or ſoda, is diſſolved, though not in a large proportion. Ammonia acts with more eaſe and without heat. If this alkali is dropped into nitrated biſmuth, it firſt precipitates an oxyd which it afterwards rediſſolves.

Biſmuth unites eaſily with ſulphur by fuſion. The ſulphuret thence reſulting is a black brittle maſs, requiring more heat to melt it than the reguline biſmuth. Three parts of biſmuth in powder, mixed with one of flowers of ſulphur and melted in a covered crucible, give a compound much reſembling the native ſulphuret, and if poured out when nearly cooled, ſix-ſided priſmatic cryſtals are found on the ſides of the crucible, projecting into the cavity left by the loſs of the fluid part. The ſulphur is eaſily ſeparated by nitric acid. The ſulphuretted alkalies alſo combine readily with biſmuth. If any of theſe is poured into an acid ſolution of

[1] Gren.

bismuth, a mutual decomposition takes place, and a black hydrofulphuretted fulphuret of bismuth is precipitated. Sulphuretted hydrogen added, either in gas or diffolved in water, to the folutions of bismuth, inftantly blackens them and precipitates a hydrofulphuret of bismuth. A *fympathetic* INK is made by this method, which is colourlefs till expofed to fulphureous vapours, which immediately blacken the characters written with the bismuthic folution. The white oxyd alfo quickly becomes of a dirty brown when expofed to fulphureous vapours even in a very fmall degree, and hence its ufe as a cofmetic is liable to fome inconveniencies.

Phofphorus can fcarcely be made to unite with bismuth, and in fo fmall a quantity as not fenfibly to alter the natural appearance.

The fat oils when melted diffolve the oxyd of bismuth with great eafe and form a thick plaftery mafs, as with the oxyd of lead.

Bismuth unites more or lefs readily with moft other metals, and fome of thefe alloys are remarkable for their extreme fufibility. Sir Ifaac Newton's fufible metal is compofed of 8 parts of bismuth, 5 of lead and 3 of tin, and when this is thrown into water and heat applied it actually melts a little before the water has reached the boiling point. No other alloy (except the amalgams, one conftituent of which is naturally fluid) poffeffes this degree of fufibility. Many experiments have been made by D'Arcet[m] on the fufibility of alloys made with different proportions of thefe three metals. In all, the alloy, if it did not actually melt, at leaft became foft and pafty at the heat of boiling water, but the proportions above given produce the moft perfect fufion. It is requifite that the bismuth be about equal in weight to both the other two metals, but the proportions of thefe latter will admit of great variation. Bismuth and lead, or bismuth and tin alone in any proportion will not foften in boiling water. Thefe alloys are moftly white, perfectly brittle, and tarnifh with great readinefs. When melted, even under water, they directly become covered with a fkin of oxydated metal, and when calcined in the open air, this oxyd forms with great rapidity, and the metal beneath conftantly becomes lefs and lefs fufible. This alloy is not commonly put to any ufe, but a fimilar though lefs fufible compofition has been ingeniouſly applied as the material of the fafety-plug to a fteam-boiler for mechanical purpofes.[n]

Bismuth is a metal very little ufed. It enters into the compofition of fome of the foft folders, but is fcarcely employed in any other way. The white oxyd is ufed in perfumery, and a little in medicine with apparent advantage. It furnifhes two amufing fympathetic inks, one as a hydrofulphuret, already mentioned, the other by precipitation of the nitrat by means of water. If characters be written with a moderately dilute nitrat they will dry invifible, but on wetting the paper the feparation of the oxyd from the nitrat will exhibit the writing in denfe white marks.

The affinities of oxyd of bismuth in the moift way, in a moderate heat are—the gallic, oxalic, arfenic, tartareous, phofphoric, fulphuric, nitric, muriatic, fluoric, fuccinic, citric, acetic, carbonic, and pruffic acids, and ammonia.

BITTER EXTRACT. See EXTRACT *Vegetable.*

BITTER PURGING SALT, or *Epfom falt.* See SULPHAT of *Magnefia.*

BITTERSALT Native. *Naturliches bitterfalz, Haarfalz. Magnefie fulfatée* of Hauy.

Its colour is greenifh white, greyifh white or fmoak-grey. It occurs fometimes earthy, fometimes in mafs, and often in capillary cryftals. When earthy it is without luftre, but when cryftallized it has a conſiderable degree of luftre between filky and vitreous. Its longitudinal fracture when in mafs is curved or radiated fibrous: it is tranflucid, very eafily broken, and has an acerb bitter tafte. It confifts of fulphat of magnefia, more or lefs mixed with iron and alumine, and probably a little fulphat of alumine.

It is found on the furface of decompofing argillaceous fchiftus and fome kinds of limeftone. The hair-falt found in the mercury mines of Idria, by Scopoli, and fuppofed by fome to be a fulphat of zinc, by others to be a variety of plumofe alum, is proved from the analyfis of Klaproth[o] to be fulphated magnefia with lefs than 1 per cent of oxyd of iron.

BITTERSPATH. *Rautenfpath.*[p] *Muricalcite* of Kirwan. *Chaux carbonatée magnefifere*, Hauy. *Spath magnefien*, Brochant. *Bitterfpath, Miemite and Prifmatic bitterfpath* of Klaproth.

The colour of this mineral is greyifh or greenifh white, paffing into afparagus green; or yellowifh pearl-grey paffing into light ochre and pale honey yellow and yellowifh brown. It occurs difſeminated or cryſtallized, in

1. Rhomboids either perfect or truncated at the folid angles (bitterfpath.)

[m] Journ de Phyf. tom. 9. [n] By Mr. Wood, of Burflem, Staffordfhire. [o] Analyt. Eff. ii. p. 80.
[p] Emmerling, Jameſon, Klaproth's Analyt. Eff. i. p. 256. ii. p. 233.

2. Short ſomewhat oblique tetrahedral priſms, often bevilled at the edges (ſtanglicher bitterſpath.)

3. Compreſſed hexahedrons (miemite.)

The cryſtals are ſmall, and very ſmall, or middle-ſized. The internal luſtre of bitterſpath is brilliant, between vitreous and pearly: the fracture is curved or ſtrait foliated, paſſing in the priſmatic variety into ſplintery: the fragments in the firſt variety are rhomboidal, in the others they are indeterminately angular. It is tranſparent or ſemitranſparent, in hardneſs equal to fluor, brittle and eaſily frangible. Sp. gr. 2.48 to 2.88.

It is infuſible before the blowpipe without addition, diſſolves in nitrous acid ſlowly, and with ſcarcely any efferveſcence; when expoſed to a red heat it does not decrepitate but becomes of a browniſh yellow colour, opake and ſoft. We poſſeſs four analyſes of this ſubſtance, and all by Klaproth.

	Bitterſpath from Tyrol.	Bitterſpath from Sweden.	Priſmatic bitterſpath.	Miemite.
Carbonat of lime	52.	73.	60	53
——— of magneſia	45.	25.	36.5	42.5
Oxyd of iron and manganeſe	3.	2.25	4	3
	100	100.25	100.5	98.5

Bitterſpath is found in chlorite and other talcoſe rocks at Brienz in Switzerland and in the Tyrol, alſo at Taberg in Sweden, and on the banks of Loch Lomond in Scotland. The priſmatic bitterſpath is met with in the cobalt mines of Gluckſbrunn in the territory of Gotha; and the miemite was diſcovered by Dr. Thomſon, at Miemo in Tuſcany.

BITUMEN.[a] *Bitume. Erdharze.*

The bitumens form a claſs of mineral inflammables diſtinguiſhed by the following properties. They burn with a bright flame and much ſmoak, leaving behind ſcarce any earthy reſidue. When diſtilled *per ſe* they do not afford either ammonia or a concrete acid. They are not ſoluble either in water or alcohol. They are not ignited by nitrous acid.

The moſt convenient arrangement of the bitumens appears to be into the liquid, ſolid and elaſtic.

Sp. I. Liquid bitumen, or mineral oil.

Var. 1. Naphtha. *Naphte. Bergnaphtha.*

Naphtha is either colourleſs or of a dilute yellowiſh wine colour: it is perfectly fluid and tranſparent; has an oily luſtre and is unctuous to the touch. It has a penetrating but not diſagreeable odour. Specific gravity according to Muſchenbroek 0.708; that of the yellowiſh kind according to Briſſon =0.845. It does not congeal at 0° Fahr.

By the ſlighteſt contact of a flaming body, naphtha takes fire, and burns with a very copious bluiſh yellow flame, a penetrating odour and much ſmoak. When diſtilled the colourleſs kind paſſes over unaltered, the coloured leaves behind a ſmall reſidue and becomes colourleſs. By long expoſure to the air it is in part volatilized, and the reſidue is hardly to be diſtinguiſhed from petroleum.

Naphtha communicates part of its aroma to water and alcohol, but appears to be inſoluble in theſe fluids; it corrodes the corks of bottles in which it is kept; it combines with ether, the eſſential oils and reſins. Pure ammonia and the cauſtic fixed alkalies unite with it into a ſavonule analogous to Starkey's ſoap.

The addition of concentrated ſulphuric or nitric acid to naphtha cauſes a violent efferveſcence, and converts it into a ſolid reſinous matter, ſoluble in alcohol.

The pureſt European naphtha comes from Monte Ciaro, near Piacenza, in Italy. This hill conſiſts of horizontal beds of argillite, in which pits are ſunk till the water comes in, after which the naphtha ouzes out of the ſides and floats on the ſurface of the water, whence it is ſkimmed off every week.[b] An inferior kind, often paſſing into petroleum, is procured at Monte Feſtino, not far from Modena, in the vicinity of which ſubterranean fires often break out.[c]

But the moſt copious ſprings of naphtha with which we are acquainted are at Baku, near Derbend, on the north-weſt ſhore of the Caſpian ſea. The ſoil is a clayey marl, ſtrongly efferveſcing with acids, and ſo thoroughly impregnated with naphtha that when turned up to the depth of a few inches it will take fire on the application of a lighted candle, and continue burning till it is purpoſely extinguiſhed; the

[a] Kirwan, ii. p. 42. Brochant, ii. p. 59. Gren, Syſtemat. Handbuch. iii. p. 2.
[b] Mem. Sci. 1736. p. 57.
[c] Ramuzini, Act. Lips. 1699.

flame is of a pale bluiſh yellow, and in calm weather riſes to the heighth of ſeveral feet. The naphtha is procured by ſinking pits, into which it percolates, and which are emptied from time to time. [d]

Naphtha is employed as an external application for ſtrains and rheumatiſm; the Perſians and Ruſſians are ſaid alſo to uſe it internally as a cordial. It enters alſo into the compoſition of ſome varniſhes.

Var. 2. Petroleum, mineral tar, foſſil tar, Barbadoes tar. *Pétrole. Steinohl, Erdohl, Bergohl.*

The colour of petroleum is reddiſh or browniſh-black; it is more or leſs tranſlucid; its conſiſtence varies according to its temperature; when warm it is as fluid as common tar, but at 32° Fahr. it becomes very viſcid: it is unctuous and clammy to the touch: it has a ſtrong diſagreeable odour and a pungent acid taſte. Sp. gr. according to Briſſon 0.878.

Petroleum is conſiderably inflammable, though by no means ſo readily as naphtha. Alcohol takes up ſome of its aroma and colouring matter. When diſtilled with water it comes over more fluid and clearer, approaching to naphtha: if diſtilled *per ſe* there firſt riſes a portion of colourleſs naphtha, then an acidulous empyreumatic watery liquor, and laſtly a thick brown empyreumatic oil; a ſhining coal remains in the retort, which after combuſtion leaves an earthy reſidue. Petroleum combines with the fat and eſſential oils, with the reſins and camphor, and by long digeſtion diſſolves ſulphur: when rectified it alſo will diſſolve caoutchouc. Sulphuric and nitric acids have the ſame effect upon it as on naphtha, but it is ſcarcely at all acted on by the alkalies.

At Kalurck, in Gallitzia, a kind of petroleum is found of a brown colour, which merits an accurate examination, as it was obſerved by M. Winterl to depoſit, by expoſure to the air, a quantity of acicular cryſtals. Theſe cryſtals from their ſolubility in alcohol, and their tinging its flame of a green colour, were ſuppoſed by him to be borax. [e]

Petroleum appears to be found for the moſt part in coal-ſtrata, or in ſecondary lime-ſtone. There is a ſpring of this ſubſtance at Coalbrookdale, in Shropſhire, originating from a ſtratum of coal: at Pitchford, in the ſame county, is a coarſe-grained ſand-ſtone highly impregnated with it. It is alſo found in various parts of France, Italy, Swiſſerland, Hungary and Sweden. A few miles from the naphtha wells at Baku, on the Caſpian ſea, are ſome very copious ſprings of petroleum, iſſuing from hillocks of the ſame ſubſtance hardened by expoſure to the air; theſe ſprings ſometimes take fire, and roll a flaming torrent into the ſea, which floating on its ſurface often covers the water with a ſheet of fire to a conſiderable diſtance. [f]

No country however produces ſo large a quantity of petroleum as the Birman empire in Aſia: the town of Rainanghong is the centre of a ſmall diſtrict in which there are 520 wells of petroleum in full activity. The country in which theſe are ſituated conſiſts of a ſandy loam reſting upon alternate ſtrata of ſtandſtone and indurated clay; under theſe is a layer of pale blue argillaceous ſchiſtus impregnated with petroleum, of conſiderable thickneſs reſting upon coal. The petroleum begins to flow into the well when it is ſunk a few feet into the argillaceous ſchiſtus, and when it begins to fail the well is deepened. It is remarkable that no water ever penetrates into theſe wells. The annual quantity of petroleum produced by the whole diſtrict amounts to more than 400,000 hogſheads. [g]

The uſes of petroleum where it abounds are very important. It ſerves the lower claſſes inſtead of oil for lamps, and when mixed with earth or aſhes it anſwers the purpoſe of fuel. A compoſition of petroleum and reſin is found to be an excellent material for covering woodwork and paying the bottoms of ſhips and boats, as it protects the timber from the attacks of inſects or marine worms. Finally, when rectified by diſtillation, it is applicable to the ſame purpoſes as naphtha.

Sp. II. Solid Bitumen or Mineral Pitch.

Var. 1. Maltha. Coheſive mineral pitch. *Zahes erdpech.*

The colour of maltha is browniſh black; it is opake, and has little or no luſtre; it is tough and ſoft ſo as to be impreſſed by the nail; its fracture is uneven: it has a ſtrong diſagreeable odour, acquires a poliſh when rubbed or cut with a knife, and does not ſtain the fingers. Sp. gr. from 1.45 to 2.06 [h]

Maltha when laid on a red hot iron immediately takes fire and burns with a large bright flame, leaving behind a ſmall quantity of grey aſhes. According to Kirwan [i] it conſiſts of bitumen mixed with about 8 per cent of carbon and a little earth. It paſſes into the following variety.

[d] Hiſt. des decouvertes Ruſſes, ii. p. 215. [e] Crell's Chim. anal. 1788 p.493. Journ. de Phyſ. xl p.315.
[f] Hanway's Trav. i. p. 263. [g] Cox in Aſiat. Reſearches, vi. [h] Kirwan Mineral. ii. p. 45. [i] Ibid. p. 522.

Var. 2. Aſphalt, Jews' pitch. *Aſphalte, Bitume ſolide* Hauy. *Schlackiges erdpech.*

The colour of aſphalt is browniſh black, rarely pure black: it occurs in maſs, or diſſeminated or ſuperficial or ſtalactitic: its fracture is ſmall conchoidal with a brilliant reſinous luſtre: it is opake, ſmooth and ſomewhat unctuous to the touch; does not ſtain or adhere to the fingers; is brittle and very eaſily broken. It gives out when rubbed a ſlight bituminous odour. Sp. gr. 1.07 to 1.65, according to Kirwan.

Aſphalt when laid on a hot iron readily takes fire, and burns with a yellow flame and copious ſmoak, it ſwells but does not properly melt; after the flame has ceaſed there remains a light ſpungy coal, which by further combuſtion diſappears, leaving a ſmall quantity of aſhes.

By dry diſtillation aſphalt yields carburetted hydrogen gas, a light brown oil, or naphtha, and a little water ſlightly impregnated with ammonia: what remains in the retort is a ſhining coal of an iron grey colour, containing charcoal, a little earth with oxyd of iron, and ſometimes of manganeſe.

100 grains of Albanian aſphalt yield by this treatment, according to Klaproth, [k]

36 cubic inches of carburetted hydrogen gas,
32 grains bituminous oil,
6 ——— water ſlightly impregnated with ammonia,
30 ——— charcoal,
7.5 ——— ſilex,
4.5 ——— alumine,
0.75 ——— lime,
1.25 ——— oxyd of iron,
0.5 ——— oxyd of manganeſe.

According to Kirwan's experiments of combuſtion by nitre, aſphalt contains 31 per cent. of carbon. [l]

Alcohol has no action on aſphalt, but the fat and eſſential oils and ether, with ſome difficulty effect a ſolution of it. The beſt ſolvent however for this ſubſtance is rectified petroleum or naphtha; five parts of this will take up in the cold one part of aſphalt, forming a ſaturated ſolution of a deep black colour, which upon evaporation leaves the aſphalt in the form of a blackiſh brown ſhining varniſh. The mineral acids have little or no action on aſphalt, and the cauſtic fixed alkalies, even when boiled upon it, are incapable of diſſolving it. [m]

Aſphalt is found at Morsfeld in the Palatinate, at Neufchatel in Swiſſerland, in large ſtrata at Avlona in Albania: it is found plentifully in detached pieces on the ſhores, or floating on the ſurface of the Dead Sea in Judea, hence called the Aſphaltic lake. It abounds alſo in the iſlands of Barbadoes and Trinidad in the Weſt Indies. In the latter of theſe iſlands there is a remarkable round plain about three miles in circumference, called the *Tar lake*, conſiſting entirely of a ſtratum of aſphalt. From its colour and flatneſs it has the appearance at a little diſtance of a lake of water, but on a nearer approach it is obſerved to be divided in every direction by deep creeks from four to ſix feet wide, and generally full of water. The conſiſtence and general appearance of the aſphalt is that of pit coal, only the colour is rather greyer: it is very brittle and breaks into ſmall cellular gloſſy fragments: ſome of the more elevated parts of the ſurface are covered with a thin brittle ſcoria. The thickneſs of the ſtratum is unknown. When it is cut into with an axe to the depth of a foot, it is ſofter and coheſive, and full of minute cells containing an oily fluid: a piece of this held to a candle makes a crackling noiſe, emitting ſmall ſparks with a vivid flame, but the combuſtion ceaſes the moment that the candle is withdrawn. When put into the fire it boils up for a long time without ſuffering much diminution, and after a continued heat the ſurface burns and forms a ſcoria, underneath which the reſt remains in a ſemifluid ſtate. A gentle heat renders it ductile, and when mixed with greaſe or common pitch it is uſed for paying the bottoms of ſhips, and is ſuppoſed to protect them from that peſt of the Weſt Indian ſeas, the teredo or borer. [n]

The uſes of aſphalt, beſides that already mentioned, are as a varniſh, and an eſſential part of the beſt wax or varniſh for the uſe of engravers. Aſphalt is often ſophiſticated by mixture with common pitch: it may however be readily diſtinguiſhed from this latter, by having little or no ſmell, by its not adhering to the fingers, by its ſuperior luſtre and minute conchoidal fracture, by its burning without becoming fluid, and by its inſolubility in alcohol.

Sp. III. Elaſtic Bitumen [o] or Mineral Caoutchouc. *Pois mineral Elaſtique. Elaſtiches erdpech.*

Var. 1. Compact mineral Caoutchouc.

The colour of this ſubſtance is yellowiſh or reddiſh-brown, hyacinth-red, olive brown and blackiſh brown. It occurs maſſive, or mamillary, or ſtalactitic, or in globular diſtinct concretions.

[k] Analyt. Eſſ. ii. p. 253. [l] Mineralog. ii. p. 523. [m] Klaproth Analyt. Eſſ. ii. p. 254.
[n] Anderſon in Phil. Tranſ. vol. lxxix. p. 65. [o] Brochant, Hatchet in Lurn. Tranſ. Fauj. St. Fond. in Ann. du Muſeum National, No. 4.

It is ſometimes viſcid and adhering to the fingers, but generally more or leſs elaſtic paſſing into brittle, in which laſt ſtate it is ſcarcely to be diſtinguiſhed from aſphalt: its colour becomes dark nearly in proportion to its hardneſs. It is tranſlucent or tranſlucent only at the edges: has a ſomewhat unctuous feel, and a ſlightly bituminous colour. Sp. gr. 0.905 to 1.233.

Mineral caoutchouc burns readily with a large flame and much ſmoak: when expoſed to a gentle heat it melts, and is converted into petroleum or maltha, or aſphalt, according to its previous conſiſtence.

Rectified petroleum when digeſted upon this ſubſtance acquires a bright yellow colour, and cauſes the bitumen to ſwell and become tranſparent, but produces no other change: it is inalterable in oils and ether, and even when digeſted for a long time with boiling nitric acid or caustic potaſh: after having been melted however it exhibits the ſame chemical properties as petroleum. [p]

Mineral caoutchouc has hitherto been found only in the Odin-mine near Caſtleton in Derbyſhire, in ſecondary limeſtone accompanied by calcareous ſpar, fluor, blende, galena, pyrites and aſphalt.

Var. 2. Suberiform mineral Caoutchouc.

Its colour is that of cream or pale ochre, but by expoſure to the air it becomes of a pale reddiſh brown colour: its texture is very minutely cellular like cork, and in the cells (according to St. Fond) is often contained an empyreumatic acidulous liquor; by ſpontaneous decompoſition it becomes friable and pulverulent; it is opake, moderately elaſtic, and has an odour like that of leather. Sp. gr. 0.974 to 0.988.

This ſubſtance is not ſo readily inflammable as the preceding variety, and when applied to a lighted candle crackles as if it contained water. In its other properties it reſembles the compact mineral caoutchouc.

It is found in a rivulet near the Odin-mine, in nodules and detached pieces, which upon being cut into often preſent a nucleus of compact caoutchouc, paſſing by inſenſible degrees to the preſent variety.

The elaſtic bitumen appears to be only a peculiar modification of petroleum in its paſſage to aſphalt, and in all probability owes its elaſticity to the moiſture with which it is combined and to its cellular texture. It will perhaps on further inveſtigation be found to differ in little or nothing from the cellular aſphalt of Trinidad.

On account of the inſolubility of mineral caoutchouc there exiſts no proper analyſis of it: from the reſults of its diſtillation and the incineration of the coaly reſidue it appears that 100 grains afford [q]

38 cubic inches carburetted hydrogen gas,
4 ——— carbonic acid gas,
73 grains bituminous oil,
1.5 —— acidulous water,
6.25 —— charcoal,
2. —— lime,
1.5 —— ſilex,
0.75 —— oxyd of iron,
0.5 —— ſulphat of lime,
0.25 —— alumine.

All the bitumens appear to be of vegetable origin, but for further remarks on this ſubject ſee COAL.

BITUMINOUS SHALE. See CLAY (Slaty.)

BITUMINOSER MERGELSHIEFER. See MARL.

BITUMINOUS WOOD. See COAL.

BLACK-JACK. See ZINC.

BLACK-LEAD. See GRAPHIT.

BLACK-WADD. See MANGANESE.

BLEACHING. *Blanchiſſage*, Fr. *Bleichen*, Germ.

The proceſs of bleaching conſiſts of a ſeries of operations, partly chemical and partly mechanical, to which vegetable and animal fibres are ſubjected for the purpoſe of diſcharging their natural colour, and thus rendering them white, either before or after they have been manufactured. Now as almoſt all the articles of cloathing are formed of vegetable or animal fibres, and as theſe are for the moſt part required to be made as white as poſſible, either to be worn in this ſtate, or as preparatory to being dyed or printed, it is obvious that the art of bleaching is one of great importance. We ſhall therefore ſtate as minutely as is conſiſtent with the plan of this work the various methods of bleaching that have been put in practice, and endeavour to explain the reaſon of their more or leſs perfect ſucceſs.

The ſubſtances upon which the bleacher is required to exerciſe his art are cotton, flax, hemp, wool and ſilk. The three former being of vegetable origin require a ſomewhat ſimilar treatment, which in many particulars differs from that which is applicable to the two latter.

In order to form a correct idea of the rationale of the various bleaching proceſſes, it is neceſſary to enquire into the nature of the colouring matter. It is to be regretted however that our information on this head is by no means ſo accurate as its

[p] Klaproth. Analyt. Eſſ. ii. p. 83. [q] Ibid, p. 87.

importance requires. Mr. Kirwan indeed has made us acquainted with the properties of the colouring matter of linen, and for want of ſimilar experiments on hemp and cotton, we muſt be ſatisfied for the preſent with concluding from analogy that the colour of theſe and all other vegetable fibres reſides in a ſubſtance of nearly the ſame properties as is found in linen.

Mr. Kirwan's method of procuring the colouring matter was by adding diluted muriatic acid to an alkaline ley, which had been ſaturated with colouring matter by being boiled with brown linen yarn.* A copious flocculent ſediment was thrown down, which when waſhed and drained on the filter was of a dark green colour and a ſoft clammy conſiſtence like moiſt clay. By being further dried it became of a ſhining black and ſomewhat brittle, and when placed on a red-hot iron it burned with a yellow flame and black ſmoak, leaving a ſmall coally reſidue. The freſh precipitate appeared to be entirely inſoluble in boiling water, or linſeed oil or the eſſential oil of turpentine. To rectified alcohol it communicated a reddiſh hue, and was in a great meaſure diſſolved; but on the addition of water the whole became milky and a white ſediment was gradually depoſited. It communicated a ſlight colour to the ſulphuric, nitric and muriatic acids, but was not taken up in any perceptible quantity. The fixed alkalies both in a mild and cauſtic ſtate, and ammonia when cauſtic, as well as the alkaline ſulphurets, effected a compleat ſolution of it and acquired a dark brown colour. Hence it appears to be a ſpecies of reſinous extract.

This being premiſed, we ſhall now deſcribe, firſt, the old method of bleaching, ſecondly, the alterations cauſed by the introduction of the oxymuriatic acid, and thirdly the more recent improvements ſuggeſted by M. Chaptal and others.

Cotton is ſeldom bleached till after it has been woven. When cotton cloth therefore comes into the bleacher's hands it contains, beſides its proper colouring matter, a quantity of ſize or paſte, with which the yarn is impregnated during the weaving. The firſt proceſs to which it is ſubjected is *ſteeping*. For this purpoſe the cloth is placed in a vat and covered with lukewarm water, where it remains for about twenty-four hours. During this period a ſlight fermentation takes place, which looſens the adheſion of the paſte and probably alſo diſpoſes the colouring matter itſelf to be more eaſily removed by the ſucceeding operations. The cloth being taken out of the ſteep is to be well waſhed in a current of clear water, and is then ready for the ſecond proceſs, or *boiling*. To effect this the goods are placed in a copper, with either pure water, or what is ſtill better, a weak alkaline ley, and by means of a winch placed over the veſſel are kept continually paſſing through the hot liquor, as long as it appears to extract any of the colouring matter; the cloth is afterwards taken out and well waſhed in clean water. To the operation of boiling ſucceeds *bucking*, which in fact is only another boiling in a ſtronger ley. The apparatus however is ſomewhat different, conſiſting of a large vat or bucking tub, connected by means of a pipe that enters its upper extremity with an iron boiler, and by means of a ſimilar pipe paſſing from the bottom of the tub, with an iron reſervoir in which a pump is fixed. The iron boiler is charged with a ſtrong ley, and when it is warm a portion of it, by turning a ſtop-cock, is tranſferred by means of the pipe into the bucking-tub: here it falls firſt on the upper part of the cloth and preſently penetrates the whole maſs. After a time the cock of the lower pipe is turned and the ley, now almoſt cold, flows into the reſervoir. A freſh quantity of hotter ley is then let into the tub from the boiler, and the contents of the receiver are thrown, by means of the pump, into the boiler again. Thus a continual circulation of the ley through the tub is effected for ſeveral hours, till the liquor becomes black, fetid, and almoſt of the conſiſtence of treacle from the quantity of colouring extract that it has taken up. The cloth is then removed and well waſhed. The next proceſs conſiſts in *expoſing it to the air*, which is done by ſpreading it out on the graſs in the bleach-field, and keeping it always damp by throwing water on from time to time. To this another bucking ſucceeds, and thus theſe two proceſſes alternate as long as any increaſe of whiteneſs is obtained. The laſt operation is that of *ſouring*. For this purpoſe a leaden cauldron is charged with water and as much ſulphuric acid as will make the mixture almoſt as ſour as lemon-juice; in this the cloth is to be immerſed for ſome hours while cold, a fire is then made under the kettle, and the liquor is heated to be rather more than blood-warm: when the goods have been in the ſours twenty-four hours they are taken out and immediately transferred to the river, where they are waſhed with particular care till all the acid is perfectly diſcharged: and the bleaching is now compleated.

* Iriſh Acad. Tranſ. 1789.

The above was the old method of proceeding before the oxymuriatic acid came into uſe; and as far as concerned the diſcharge of the colouring matter it was certainly very effectual. If the leys however were too hot or too ſtrong, the toughneſs of the cloth was liable to be injured, and even under the moſt favourable circumſtances a great conſumption of time neceſſarily enſued. The proceſs could not be carried on in the four winter months; and from four to ſix buckings and as many weeks expoſure to the air were required to bring cotton goods to their utmoſt whiteneſs.

The diſcovery of oxymuriatic acid was made by Scheele in the year 1774, and the efficacy of this elaſtic fluid in diſcharging the colour from vegetable ſubſtances was ſoon after noticed by the ſame able chemiſt; the diſcovery was communicated by him to Mr. Kirwan, who perceiving the probability of its being applicable to the art of bleaching, ſuggeſted this uſe of it to Mr. C. Taylor, at that time a partner in a calico manufactory near Manchester. By the exertion of this gentleman and his partners, "a whole piece of calico in the ſtate received "from the loom was, in the ſpring of 1788, "actually bleached white and printed in per- "manent colours, and produced in the Man- "cheſter market ready for ſale, having under- "gone all theſe operations in leſs than 48 "hours.[b]" M. Berthollet was in the mean time engaged in a courſe of ſimilar experiments, the reſults of which he publiſhed in 1789,[c] and from this period the uſe of the oxymuriatic acid was rapidly introduced into the bleacheries of England, France and Germany, with conſiderable and increaſing ſucceſs. The bleaching liquor of M. Berthollet conſiſted merely of water impregnated with oxymuriatic acid gas, but this was found to be ſubject to a number of inconveniencies: it was troubleſome in the preparation, was eaſily ſpoiled on expoſure to the air on account of the volatility of the acid, its odour was ſo ſuffocating that it was with the utmoſt difficulty that the workmen could make uſe of it, and it not only diſcharged the natural colour of the cloth, but greatly weakened and impaired the colours communicated to it by dying, which confined its uſe to white goods. Some manufacturers at Javelle, in France, were induced to add a ſolution of cauſtic potaſh to the bleaching liquor, by which, though the *rapidity* of its action was in ſome degree diminiſhed, yet its bad effects were very conſiderably mitigated; the proceſs was thus however rendered much dearer on account of the additional coſt of the alkali. In 1798, Mr. Tennant, of Glaſgow, at length ſucceeded in the preparation of liquid oxymuriat of lime, and thus produced a bleaching liquor more ſafe and efficacious in every reſpect than the oxymuriat of potaſh, as well as greatly cheaper. The ſame ſkilful chemiſt has ſince carried the preparation of this article to perfection by procuring it in a ſolid ſtate, in which it may be tranſported to any diſtance, and kept in barrels for almoſt any length of time without being injured.

In the new mode of bleaching cotton, all the proceſſes as far as the firſt bucking are the ſame as before, but when this is compleated the goods, inſtead of being laid on the graſs to whiten, are immerſed for about half an hour in a dilute ſolution of oxymuriat of lime; being then taken out and waſhed they are again boiled in an alkaline ley, and afterwards ſteeped in oxymuriat of lime, thus alternating theſe proceſſes till the requiſite whiteneſs is obtained. The cloth is then to go through the proceſs of ſouring as before, and finally is to be immerſed in a weak ley of pearlaſh or ſoap, to prevent a ſlight yellowiſh tinge which the uſe of oxymuriatic acid would otherwiſe occaſion.

The *oxygenating* proceſs of bleaching, by the uſe of oxymuriat of lime, appears to be perfect, whether we regard its ſafety, its expedition, or its cheapneſs, and the only further improvement to be required in the art, as far as the preparation of white goods is concerned, is to ſimplify and ſhorten the *bucking*, or thoſe parts of the proceſs in which the cloth is ſubjected to the action of alkali. A very ingenious and ſimple method of effecting this has been ſuggeſted by M. Chaptal, and the experiments which have been made appear to confirm the value of the propoſed alteration. M. Chaptal's method conſiſts in expoſing the cloth when impregnated with ca tic alkali to the action of ſteam raiſed to a ſomewhat higher temperature than that of boiling water.[d] For this purpoſe a ſquare or rectangular ſhallow boiler is firmly fixed in maſonry, and a vault of ſtonework lined with lead is raiſed over it; at one end is a door ſufficient to admit a man, made to fit very cloſely, and capable by the action of ſcrews of being rendered ſteam-tight. Within the vault are fixed reels, by means of which either cloth or yarn can be wound off one on to the other, by a ſomewhat circuitous route, during which it is made to paſs through the liquor in the boiler and is alſo expoſed to the action of the ſteam.

[b] Rees's Cyclopedia, art. Bleaching. [c] An. de Chim. ii. p. 257. [d] O'Reilly ſur le blanchiment.

The cloth or yarn being previouſly ſteeped for a few hours in an alkaline ley is wound upon one of the reels, and a quantity of ley is alſo poured into the boiler; the door of the vault is then ſecured and the fire under the boiler is lighted. This being done, the cloth is ſlowly transferred from one reel to the other, and afterwards returned to the former one, by means of a winch worked by hand or machinery on the outſide of the vault. This being performed in a denſe atmoſphere of very hot ſteam, and the cloth in one part of its progreſs paſſing through the liquor in the boiler, the colouring matter of the cloth is much more ſpeedily extracted than by the common proceſs of bucking. Hence not only time is ſaved but the beating to which the goods are ſubjected in the waſh-wheel, and by which their ſtrength is in ſome degree injured, may be conſiderably leſſened.

The colouring matter of flax and hemp is not only greater in quantity but appears to adhere more firmly than that of cotton; in conſequence of which, though the general proceſs for bleaching goods made of theſe materials is preciſely the ſame as that which is employed for cotton, yet the ſtrength and number of alkaline leys made uſe of is conſiderably greater. It is probable therefore that in the bleaching of linen, Chaptal's proceſs (which we have juſt mentioned) might be adopted with the moſt decided advantage.

We have already noticed the experiments of Mr. Kirwan on the colouring matter of flax; this able chemiſt found that it was ſoluble not only in the pure cauſtic alkalies but alſo in the hydroſulphuretted alkalies. It is probable that this fact ſuggeſted to Mr. W. Higgins, of Dublin, the uſe of hydroſulphuret of lime inſtead of potaſh, an alteration which, if finally confirmed by experience, will be of the moſt ſerious advantage to the country by ſaving an enormous expence in an article for the whole of which we are dependent on foreigners. Mr. Higgins's method of bleaching Iriſh linen is the following. The linen as it comes from the loom is charged with the weaver's paſte or dreſſing, to get rid of which the cloth is ſteeped in water for 48 hours and then well waſhed: it is afterwards immerſed in a cold ſolution of hydroſulphuret of lime for 12 or 18 hours; being then waſhed and dried it is ſteeped in oxymuriat of lime for 12 hours. The linen is to be ſix times alternately immerſed in each liquor, at the end of which operation it will be ſufficiently white, and is then to be finiſhed in the uſual manner.

The rationale of the bleaching proceſs for vegetable fibres is not yet very ſatisfactorily made out; thus far however ſeems to be tolerably clear. The colouring matter of the cloth or yarn when it comes into the bleacher's hands conſiſts of two portions, one ſoluble in alkali, the other not, or at leaſt requiring for this purpoſe a ley of ſo great a ſtrength as would alſo act on the vegetable fibre itſelf. When the ſoluble part is removed by the alkali, it is neceſſary either to expoſe the cloth for ſeveral days to the light and air, or to ſubject it to the action of oxymuriatic acid before a freſh portion of colouring matter can be rendered ſoluble in a ley of ſuch a ſtrength as it is ſafe to employ. It appears probable that the change in the colouring matter is entirely owing to an abſorption of oxygen, and it would be a ſubject of curious enquiry to examine in what ſtate the colouring matter is previous to oxygenation. It is not likely that it ſhould be a perfect reſinous extract, otherwiſe it ought to be entirely ſoluble in the firſt alkaline ley.

The *animal* fibres that are ſubjected to the bleaching proceſs are wool and ſilk. Theſe cannot be treated in the ſame manner as vegetable ſubſtances: a ſtrong alkaline ley will diſſolve them, and oxymuriatic acid will both weaken them and turn them yellow.

The colour of manufactured wool reſides partly in its own oil, and partly in the greaſy and mucilaginous applications which it receives in being prepared for the loom. Both the one and the other are eaſily got rid of by the action of fuller's earth and ſoap in the proceſs of fulling. Fuller's earth is a very fine-grained abſorbent earth, which by itſelf is capable of mixing rather than combining with vegetable or animal oils, and rendering them miſcible with water; its action is found however to be increaſed by the addition of ſoap; and woollen cloth being beat in a fulling-mill with hot water, and a proper mixture of earth and ſoap, or of ſoap alone, and afterwards well waſhed and dried in the air, receives all the bleaching which it requires or is indeed capable of. It is then of a white colour, ſomewhat verging towards yellow; this laſt tinge may be made to diſappear by the addition of a very ſmall quantity of ſtone blue in the water in which the cloth is laſt waſhed, or by expoſing it to the fumes of burning ſulphur; by this latter method however it acquires a certain harſhneſs of feel and is apt to turn very yellow when waſhed with ſoap.

Both the colour and harſhneſs of raw ſilk depend entirely on a yellow varniſh with which it is naturally covered. This varniſh may be in

part removed by long boiling in ſimple water. It is conſiderably more ſoluble in alcohol, but the moſt effectual and expeditious way of clearing it is by putting it in a linen bag and boiling it for ſome hours in a ſolution of white ſoap in water, then rincing it in clean water and repeating the proceſs till it is quite white and exhibits the peculiar luſtre of this beautiful ſubſtance. Some of the French chemiſts have endeavoured to leſſen the conſumption of ſoap by propoſing various ſubſtitutes, but nothing is ſo effectual and expeditious as the pureſt white ſoap, and the article itſelf is ſo valuable as amply to repay this expence.

BLENDE. See ZINC (Ores of.)

BLOOD. This moſt important of all the animal fluids requires a pretty minute examination, both on account of the many intereſting facts which its analyſis preſents, and as ſerving in ſome meaſure to illuſtrate the general hiſtory of animal matter, and alſo as it has engaged the attention of a multitude of excellent chemiſts with very great ſucceſs and advantage to the ſcience in general.

Blood when juſt drawn from the veins of all the warm-blooded animals (which includes man, moſt quadrupeds, birds, and the cetaceous fiſhes) is a ſmooth opake uniform red liquid (crimſon from the arteries), conſiderably denſer than water, having a peculiar ſub-nauſeous odour, and a ſweetiſh and ſomewhat ſaline taſte. Its ſpecific gravity is found to vary from about 1.053 to 1.126; its temperature in the living animal is uſually from 96° to 100°.

The moſt remarkable circumſtance in blood, and one in which it differs from every other fluid in nature, is the ſpontaneous coagulation which takes place not long after it is drawn, and which ſeparates it into two portions, the coagulated part which is a red tough cake called the *craſſamentum*, *clot*, or *cruor*, and the clear yelloviſh liquid in which the coagulum ſwims, called the *ſerum*. This ſpontaneous analyſis has been the guide to chemical reſearches, and experiments have ſhewn both theſe ſubſtances to be further ſeparable into ſeveral elementary principles, that is, the craſſamentum, into the *red globules*, and the proper coagulable *gluten* or *fibrin*; and the ſerum into *albumen*, *gelatin* and ſeveral *ſalts*, all diſſolved in a conſiderable quantity of *water*.

The circumſtances that affect the ſpontaneous coagulation ſhould firſt be noticed. From a healthy perſon the blood generally begins to ſtiffen in about five minutes, and becomes of the conſiſtence of jelly, ſome time after which a clear liquid will be ſeen to ouze out and gradually to occupy the ſides and bottom of the veſſel, whilſt the red clot contracts in dimenſions, encreaſes in firmneſs, and after ſeveral hours appears as a tough cup-like maſs, retracted at the edges, on the ſurface expoſed to the air of a much more florid red than when iſſuing from the vein, but all below the line in which it floats in the ſerum, of a dark blackiſh red. The cauſe of this change of colour has been with great probability ſuppoſed to be the action of the air, as will be preſently mentioned.

There are three circumſtances to which the ſpontaneous coagulation of blood has been attributed, namely, to cooling, to the air, and to reſt. Theſe have all been examined in a very ſatisfactory way by a late eminent phyſiologiſt. [a]

If blood as it ſprings from the vein is received into a veſſel ſet in a ſharp freezing mixture, it does indeed congeal very ſpeedily and becomes ſolid, but on being thawed it reſumes its original fluidity, and *then* coagulates into ſerum and craſſamentum as uſual, and nearly in the uſual time, beginning to reckon from its thawing. This ſhews moſt ſatisfactorily that coagulation of blood is not congelation, nor is it at all an effect of loſing its natural heat by expoſure to air. [b] On the other hand if the blood is received into a cup ſet in water heated to about 105, it coagulates very completely, and even *ſooner* than it would do if ſuffered to cool in the atmoſphere. [c] Hence it follows that the heat the moſt favourable to this proceſs is not leſs than about the natural warmth of the blood. A greater heat will alſo promote this change.

The effect of reſt alone on blood is ſhewn by ſimply intercepting a portion of blood in a large vein of a living animal by means of ligatures, and ſuffering it to remain in its natural ſituation in the vein for a given time. Under theſe circumſtances Mr. Hewſon found that the blood contained in the intercepted portion of vein (and therefore at reſt, in the natural temperature, and excluded from air), inſtead of coagulating in about ten minutes remained partly fluid for upwards of three hours, and hence it follows that ſomething beſides mere reſt muſt contribute to produce the ſpeedy ſeparation that takes place in blood that is drawn.

This appears to be in a conſiderable degree the action of the air, for if a portion of air is confined in contact with blood at reſt in the vein of a living animal, coagulation *now* proceeds

[a] Hewſon on the Blood. [b] Hunter. [c] Hewſon.

with much greater rapidity than when no air is preſent. However, Mr. Hewſon alſo found that blood, iſſuing from a vein, and received in a phial which was corked up as ſoon as full, coagulated quite as ſoon as another portion of the ſame blood received in an open cup; and therefore, whatever effect the firſt impreſſion of air may have upon fluid blood, its influence is not at all required during the whole time of coagulation.

Two circumſtances alſo pointed out by the ſame acute phyſiologiſt, ſhew that the ſpontaneous coagulation of blood is not to be accounted for merely on common chemical principles, but depends very conſiderably on the ſtate of the *living* animal.

If recent blood is received from the veins ſucceſſively in different veſſels, the laſt portion will be found to coagulate ſooner than the firſt, and if a faintneſs comes on in the animal, the blood drawn in that ſtate will flow with extreme difficulty, and will coagulate almoſt inſtantly. This is ſimilar to what occurs in ſlaughtering beaſts, it being commonly obſerved by butchers that the blood flows thicker, and at laſt hardly flows at all when life is juſt ebbing out. From this and other facts it appears that coagulation is eſſentially regulated by the vital powers of the animal at the time that it is loſing blood from its veſſels.

When blood is drawn from a perſon labouring under an acute inflammation, affecting the general ſyſtem, it is uſually much ſlower than uſual in coagulating, and, if narrowly inſpected, the ſurface inſtead of being of a florid red becomes tranſparent to a certain depth, then of a pearly whiteneſs, and at laſt, when the coagulation is compleat, the craſſamentum is covered with a very tough grey opake cruſt often nearly to half its thickneſs, under which lie the red globules as uſual. In this proceſs nature makes a further analyſis of the craſſamentum, the grey opake cruſt being the pure *fibrin* ſeparated from the globules, which laſt, owing to the tardineſs of coagulation, ſubſide as uſual, but ſeparate, or nearly ſo, from the fibrin, which is longer held in ſolution, and therefore appears on the ſurface of the coagulum of its natural grey colour.

Several other facts are aſcertained concerning the effects on coagulation of blood produced by a variety of circumſtances affecting the powers and functions of the *living* animal, but theſe are out of the province of pure chemiſtry.

If blood is briſkly ſtirred with a ſtick as it flows from the vein, part of the fibrin collects pure about the ſtick, and the remainder will not coagulate by reſt. Moſt of the neutral ſalts if ſtirred in freſh blood in conſiderable proportion, unite very uniformly with it and totally prevent the ſpontaneous coagulation. But if this ſalted blood is diluted with water the power of coagulation returns. Thus half an ounce of Glauber's ſalt mixed with ſix ounces of blood preſerved its fluidity, but on being diluted with twice the quantity of water blood-warm, the whole ſoon coagulated very completely.[a] The uncoagulated ſaline mixture on ſtanding, gradually depoſits the red particles, leaving a clear colourleſs liquor like mere ſerum in appearance, but proved ſtill to contain the fibrin by its coagulating when diluted with water.

Nitre and ſome other ſalts render the blood florid.

The fibrin may be coagulated from the undiluted ſalted blood by applying a heat of about 120°. In doing this care muſt be taken not to raiſe the heat much higher, as this would alſo ſeparate the albumen, which coagulates from the ſerum at about 160°, though it will not ſeparate ſpontaneouſly at a lower temperature as the fibrin does. Indeed this circumſtance forms almoſt the only aſcertainable difference between the two ſubſtances. When both are coagulated together they cannot be ſeparated.

To proceed with the chemical analyſis of blood.

1. The craſſamentum when compleatly coagulated and in its natural ſtate, is of the conſiſtence of very firm gelly, but ſtill containing a good deal of ſerum, which it has entangled during its coagulation, and which oozes out copiouſly whenever the coagulum is cut into. The craſſamentum is formed of two principal parts, the fibrin, and the red globular or colouring part. The former has already been mentioned to form the tough grey cruſt of inflamed blood, and alſo to be partly ſeparated by ſtirring recent blood before it has time to coagulate. It is alſo obtained by waſhing out the red colouring part in the following way: put the whole coagulum in a linen cloth looſely tied up, and ſuffer a very ſmall ſtream of water to drop on the outſide of the bag, or elſe immerſe the bag in cold water, at the ſame time preſſing it very gently to and fro with the fingers. The water comes away of a fine claret-crimſon, carrying with it the entangled ſerum, the colouring part, and every thing but the fibrin, which at laſt is left alone in the bag, and appears as a ſtringy

[a] Hewſon.

grey elaſtic maſs, abſolutely inſoluble in water. Much patience is however required to ſucceed in this proceſs, and only very little preſſure ſhould be uſed at firſt.

Fibrin[e] when dried at a gentle heat loſes about two-fifths of its weight, and thereby becomes hard and brittle. Before drying it has a remarkable toughneſs and elaſticity, not unlike that of elaſtic gum. When ſcorched it ſhrinks and coils up like parchment. By dry diſtillation it gives a ſtrongly ammoniacal liquid, a fetid thick oil, and much concrete carbonated ammonia. The coal which it leaves contains phoſphat of lime, and is very difficultly incinerated. This earthy ſalt is detected by diſſolving the ſoluble part of the coal in nitric acid and adding ammonia, which precipitates the phoſphat of lime undecompoſed. It contains no iron. Fibrin when moiſt and kept from drying ſoon putrefies in a warm air; under water it is gradually converted into ADIPOCIRE.

Water has no action upon it; when long boiled in water it becomes hard and tranſparent like horn. The fixed alkalies and concentrated ſolutions even of the alkaline earths, diſſolve it in a boiling heat, with the evolution of ammonia, and produce a brown bitter ſaponaceous compound, decompoſable by acids and metallic ſalts. Acids, even when dilute, diſſolve it without difficulty. Nitric acid, if dilute and digeſted without heat, cauſes azotic gas to be given out, which in this caſe comes from the fibrin and not the acid; if concentrated and heated, the fibrin and nitric acid are mutually decompoſed and evolve much carbonic and pruſſic acids, with nitrous gas and nitrous oxyd, and the reſidue contains oxalic acid. All the acid ſolutions of fibrin when evaporated nearly to dryneſs, give on cooling a ſtiff gelly. Neither fixed nor volatile oils act upon it. Alcohol hardens its texture very conſiderably and ſhrinks it.

From all theſe circumſtances it is fully proved that the fibrin of blood bears the ſtrongeſt reſemblance to the *fleſh* or *muſcular fibre* of animals, and from its copious evolution of ammonia by diſtillation, and other characters, fibrin appears to contain a greater portion of azot than any other animal ſubſtance. See FIBRIN.

The red colouring part is ſingularly diſtinguiſhed by being compoſed of an infinite multitude of globules, viſible in a microſcope of high power, the conſtruction of each of which has been thought by Hewſon to be that of an external veſicle, incloſing a ſphere apparently ſolid; their diameter he eſtimates at about $\frac{1}{300}$ of an inch. Dilution with water deſtroys the globular appearance, but not with ſerum, urine, and many ſaline ſolutions. Many other curious microſcopical obſervations belong to this ſubject.

The red water uſed for waſhing the craſſamentum and ſeparating the fibrin, contains the whole of the red colouring matter. This water is ſlightly alkaline, as ſerum is, and when boiled a brown ſcum riſes to the top, conſiſting chiefly of coagulated albumen, together with the proper colouring matter, but no method has yet been deviſed for totally ſeparating theſe ingredients. The water after the ſcum has been removed is ſtill red, and when evaporated gives to the laſt ſucceſſive pellicles of brown ſcum, ſimilar to that which is formed by the firſt boiling.[f] The red globular part of blood alone contains the *iron* of this fluid, and as far as analyſis has yet gone, this metal in the ſtate of phoſphat, and a certain admixture of ſerum, are all the conſtituents of this moſt curious ſubſtance.

The exiſtence of iron in blood was firſt diſcovered by Menghini, and the experiments that ſimply ſhew its preſence are obvious. Tincture of galls mixed with blood gives it an inky blackneſs, and if the craſſamentum be dried it is ſtrongly magnetical. But the preciſe ſtate of this metal in the red colouring part is more difficult to be aſcertained. To this object Fourcroy and Vauquelin made the following intereſting reſearch. On burning in a crucible the coagulated ſcum of the red liquor in which the craſſamentum had been waſhed, they obtained a deep red ferrugineous powder, forming at firſt about $\frac{1}{200}$ of the blood employed, but ſtill mixed with the coal of the albumen and other impurities. Very weak nitric acid diſſolved out of the reſidue nearly all the iron, which ſolution, ſuperſaturated with ammonia, gave a white precipitate. This again was put, while yet moiſt, into cauſtic potaſh, which rediſſolved moſt of the precipitate. The liquor now contained phoſphat of potaſh, of ammonia and of iron, together with an exceſs of alkali, and by adding lime-water the preſence of the phoſphoric acid was proved by a precipitate of phoſphat of lime. To confirm the poſſibility of a phoſphat of iron and an exceſs of fixed alkali in the ſame liquid, they obſerved that there are two kinds of phoſphat of iron, of which one is grey, inſoluble in water, ſoluble in acids, and contains the phoſphoric acid and the iron in mutual ſaturation; the other is of a reddiſh brown, leſs ſoluble in acids, and contains an exceſs of iron, ſo that it may be called

[e] Fonrcroy Syſt. des Conn. Chim. [f] Fourcroy and Vauquelin.

a *ſub-phoſphat of iron*. Cauſtic alkalies added to the former phoſphat only partially decompoſe it, and by taking away a portion of the phoſphoric acid, reduce the remainder to the ſtate of ſub-phoſphat of iron. This too agrees with the habitudes of ſome of the other phoſphats with regard to partial decompoſition. Now as the blood always contains an exceſs of ſoda, the abovementioned chemiſts ingeniouſly explain thereby the red colour of the blood, by ſuppoſing the phoſphat of iron to be conſtantly kept by the ſoda in the ſtate of ſub-phoſphat. They likewiſe endeavoured with ſucceſs to produce a kind of artificial blood, as far as colour was concerned, by diſſolving a ſub-phoſphat of iron in white of egg or in ſerum of blood, which was very readily effected even in the cold, and gave a blood-red fluid, the colour of which was further heightened by a ſmall admixture of cauſtic fixed alkali.

The craſſamentum of blood therefore, from what has preceded, is found to conſiſt chiefly of the fibrin, and a phoſphat of iron mixed intimately with a portion of ſerum into a peculiar red ſubſtance, which under the microſcope exhibits an appearance of a vaſt multitude of globules, of a determinate ſhape and ſize.

2. The ſerum of blood is the clear yellow liquor in which the craſſamentum floats after it is coagulated. Its taſte is ſomewhat ſaline and peculiar, when agitated it froths readily and has a clammy feel to the fingers. Its ſpecific gravity is about 1.027, according to Jurin and Muſchenbroek. It immediately turns ſyrup of violets green, and gives other marks of an exceſs of alkali which analyſis confirms. This alkali is ſoda. It readily unites with water, but by large dilution it turns milky.

When ſerum is heated to 160° or upwards, a large quantity of a whitiſh ſubſtance coagulates, ſo as almoſt entirely to ſolidify the ſerum, but on cutting up the coagulum a conſiderable proportion of a thinner watery liquid oozes out, which is called by phyſiologiſts the *ſeroſity*. The coagulated maſs, if gently heated for a little time, becomes hard, brittle and horny. It agrees ſo preciſely in every chemical character with the white of egg and the other ſubſtances of this ſpecies, that it is juſtly reckoned as pure ALBUMEN, the properties of which are deſcribed under that article. If this albumen is calcined with a ſtrong heat it burns with the uſual products, and leaves in the coal a ſaline mixture conſiſting of muriat, phoſphat, and carbonat of ſoda. Theſe ſalts are foreign to what may be conſidered as the true conſtituents of albumen, and muſt therefore be added to the liſt of component parts of blood, except the latter, which inſtead of a carbonat muſt be conſidered as naturally pure ſoda, having been doubtleſs carbonated during the calcination.

Alcohol added to ſerum alſo coagulates the albumen, as it does any other albuminous liquid. Acids do the ſame, the more compleatly as the acid is more concentrated, and after coagulating the albumen they unite with the exceſs of ſoda, forming the reſpective ſalts with this alkaline baſis.

Another ſubſtance held in ſolution in the ſerum is *gelatin*. This is obtained by boiling diluted ſerum to coagulate the albumen, and then ſeparating the clear liquid or ſeroſity, evaporating it ſlowly nearly to dryneſs, and cooling. It will then appear as a ſtiff gelatinous maſs, poſſeſſing all the properties of gelatin, though mixed with all the ſalts of the ſerum. Parmentier and Deyeux[a] in their very elaborate analyſis of blood, obtained the gelatin in a leſs exceptionable way. They heated ſome pure ſerum in a water bath, whereby the albumen was coagulated, and then inſtead of ſeparating the ſolid from the fluid part, they continued the evaporation half an hour longer. The reſidue was white and cellular underneath, and each of theſe ſmall cells contained a thick yellow tranſparent ſubſtance, which reſembled in its properties the pureſt glue. The gelatin is only found in the ſerum, and was obſerved by theſe chemiſts to vary conſiderably in proportion in different perſons and animals, without being obviouſly connected with any ſtate of health or diſeaſe, or any kind of food or habitudes of the animal that furniſhed it.

Sulphur is another ingredient in blood, and is found in a minute quantity in the coagulated albumen, being indicated by blackening ſilver and producing the odour of ſulphuretted hydrogen with acids. If the albumen of blood is heated in a ſilver veſſel, the latter will become of a deep blackiſh-brown, in the ſame way that ſulphur tarniſhes poliſhed ſilver. If nitrated ſilver be triturated with albumen, and the mixture digeſted for ſome time in a moderate heat, a black precipitate of ſulphuretted ſilver is produced, from which the ſulphur might readily be extracted. A ſimilar indication of ſulphur is ſhewn by the whites of boiled eggs, which every one knows will blacken a ſilver ſpoon almoſt immediately on touching it.

Laſtly, the ſeroſity or aqueous portion of the

[a] Journ. de Phyſ.

ſerum deprived of its albumen by coagulation, if evaporated to dryneſs gives, beſides gelatin and uncombined ſoda, a ſmall quantity of muriat of ſoda, muriat of potaſh, phoſphat of lime, and phoſphat of ammonia, all of which may be detected by the proper chemical reagents.

The proportion of the conſtituent parts of blood is ſo extremely variable as probably to be ſcarcely the ſame in any two individuals. The varying quantity of craſſamentum is the moſt palpable, and has long been obſerved by phyſiologiſts and medical obſervers. It appears to be the part the moſt intimately connected with the ſtrength and vigour of bodily habit, and is the lateſt to return to its natural quantity after any great loſs of blood, ſevere evacuation, deficient nutriment, or debilating illneſs. It is alſo, *ceteris paribus*, more abundant in adult than in young animals.

It has been doubted whether the red colour of blood was owing to the iron which it contains, though the proportional quantity of this metal mixed with any colourleſs albuminous fluid, in the ſtate of ſub-phoſphat with exceſs of alkali, is ſufficient to produce as full a body of colour as that of blood. The ingenious arguments brought againſt this explanation of the cauſe of the colour by Dr. Wells,[h] belong more to optics and the theory of colours than to chemiſtry, and we ſhall therefore not enter into them.

But there is another part of this ſubject properly belonging to chemical phyſiology, which ſhould not be entirely unnoticed. This is the cauſe of the difference between *venous* and *arterial* blood. The blood contained in all the arteries of the body derived from the aorta, and alſo in the pulmonary veins, has a bright florid or vermillion colour, that of the other veins and the pulmonary artery, on the other hand, is of a dark black red; the former is termed the arterial, the latter the venous blood. The difference between the colour of the two is at once apparent when any deep wound has been inflicted, when the arterial blood will be as much diſtinguiſhed by its more florid red, as by its manner of flowing by jerks correſponding with the pulſe. The cauſe of this difference of colour is unqueſtionably owing to ſome change produced upon the venous blood as ſoon as received in the lungs, for the blood coming to the heart from the different veins of the body, goes from thence *to* the lungs by the pulmonary artery, *black-red*, and returns *from* the lungs by the pulmonary veins, *vermillion red*. This fact was obſerved long before the cauſe was accounted for, though the circumſtance of air being conſtantly admitted into the lungs made it probable that the air was in ſome way or other the cauſe of this change, and it had been thus conjectured by ſeveral phyſiologiſts.

The experiments of Dr. Prieſtley are the firſt which directly tended to confirm this very probable opinion, by ſhewing that the contact of air will produce the ſame change of colour out of the body as in it. This eminent philoſopher took part of the craſſamentum of the venous blood of a ſheep,[i] laid it on a net of gauze or wire, and introduced it into different kinds of air. Common air ſoon gave it a florid red colour, but dephlogiſticated (oxygen) air produced this change in a much more compleat and rapid manner. On the other hand the brighteſt red blood became preſently black in hydrogen, nitrous gas, azot and any other air unfit for reſpiration. Now as common air is compoſed of oxygen and azot, and as the former gives a florid arterial colour to venous blood, but the latter only renders it darker, approaching to black, it follows that it is only the oxygenous part of the atmoſphere which effects this change of colour in the lungs. From the ſame cauſe it is owing that the *ſurface* of venous craſſamentum gradually becomes of a bright red in coagulation, whilſt the under part is nearly black; and if the coagulum is turned upſide down, the part that was at the bottom, being now in contact with air, gradually aſſumes the ſame florid hue.

The blood however is not in actual contact with the air in the lungs, being ſeparated from it by the fine membrane (thinner than the thinneſt bladder) which lines the air-cells and the coats of the extreme ramifying veſſels of the pulmonary artery and veins. Hence it is requiſite to do away the objection that might ariſe from this ſource againſt the opinion of the action of air on venous blood, to ſhew that the interpoſition of a thin membrane does not prevent their mutual action. Dr. Prieſtley accordingly found that when black blood was tied up in a bladder, moiſtened with ſerum and expoſed to air, the change to florid colour was produced nearly as ſoon as when freely immerſed in air.

Another objection to be removed was that, the colouring part of blood is in its natural ſtate mixed with and immerſed in ſerum, which muſt have ſome effect in ſeparating it from the actual contact of air, but Dr. Prieſtley alſo found that the ſame change of colour happened when a piece of craſſamentum was covered even

[h] Phil. Tranſ. 1797.

[i] Experiments on Air, vol. iii.

to ſome inches with clear ſerum. On the other hand the lighteſt coating of oil, or even water, totally protected the black craſſamentum from this action of air, ſo that there is ſomething very unaccountable and ſurprizing in this ſuppoſed power of ſerum to tranſmit the influence of air. Milk is ſimilar to ſerum in this reſpect.

The change of florid blood back to dark-coloured cannot however with ſo much certainty be inferred to be occaſioned by any unreſpirable air, for though it does take place under theſe circumſtances, it will alſo happen when arterial blood is ſimply kept in a glaſs tube hermetically ſealed for ſome days, and if kept in a warm temperature the black colour appears much ſooner. Haſſenfratz alſo found that arterial blood loſt its florid colour and became of a purple red in a few days, even though kept in conſtant contact with oxygen gas.

It is ſtill doubtful what is the preciſe action of oxygen on venous blood in changing it to arterial, but theſe, and a multitude of other curious enquiries on the chemical action of the gaſes on blood, belong more peculiarly to the ſubject of reſpiration.

All the ſtronger acids when added to blood darken its colour at the ſame time that they coagulate its albumen. Sulphuric acid chars it, as it does moſt vegetable and animal matter, with diſengagement of ſulphureous acid gas. Nitric acid diſengages much azot, and the reſidue contains adipocire mixed with oxalic acid. The oxygenated muriatic acid immediately renders it as black as ink, a very curious circumſtance which would not beforehand be expected conſidering the very oppoſite effect of oxygen gas.

The vegetable acids act on it but feebly, the gallic at once detects the preſence of iron. Alkalies render blood more fluid, and rediſſolve the coagulum formed either ſpontaneouſly or by acids.

Blood very readily putrefies in a warm place, during which it becomes exceſſively fetid, the coagulum loſes its texture, and finally much ammonia and carbonic acid are diſengaged.

The effects of mere heat upon entire blood remains to be mentioned. If kept at a heat not exceeding that of boiling water it coagulates, becomes of a liver-brown, and by frequent ſtirring dries up into a black greaſy-feeling paſte, ſtrongly attracted by the magnet and capable of being kept in a dry place without alteration for a great length of time. If gently moiſtened it becomes covered with efflorescences of carbonat of ſoda. If the dried blood is further heated in an open crucible it ſoftens, puffs up, takes fire, and burns with a ſtrong flame and a very fetid ſmell. The products of this combuſtion are firſt an ammoniacal water,[k] then a pungent vapour of carbonated ammonia, then a denſe yellow ſmoke, and after it ſome pruſſic acid, diſtinguiſhable by its ſmell like bitter almonds, and laſtly jets of phoſphoric flame, ariſing from the decompoſition of the phoſphoric ſalts by means of the carbon of the blood. Carbonat of ſoda is left behind, mixed with a black cryſtalline, nearly metallic oxyd of iron, a charcoal alſo ferrugineous, and phoſphat of lime, with a little muriat of ſoda and of potaſh. If the dried blood is calcined in an earthen retort, the products are ſomewhat different but equally ſtrongly ammoniacal, and the coal has a remarkably gliſtening metallic appearance, much reſembling plumbago and very difficult to burn to aſhes.

Blood is of no inconſiderable uſe out of the body. Some people uſe the blood of cattle largely as food mixed with meal of one kind or another. When intended for this purpoſe it is ſtirred briſkly as it flows from the vein, whereby, as above mentioned, its coagulation is prevented, and it is then ſtirred into the meal and dried, or cooked in any other way. The coagulating property of blood renders it of conſiderable uſe in clarifying thick mucilaginous liquors. Cyder is ſometimes fined in this method, being ſimply beat up cold with blood and put into a barrel. On ſtanding a day, the entire coagulum of the blood, with the impurities of the cyder, are found lying at the bottom in a tough cake, and the liquor above is quite tranſparent and nearly colourleſs.[l]

Pruſſian blue is alſo made by firſt calcining blood with an alkali, whereby the pruſſic acid, which as above mentioned flies off during calcination *per ſe*, is detained in union with the alkali, and is afterwards made into PRUSSIAN BLUE by ſulphat of iron. Laſtly, blood is eminently uſeful as a manure, and as a material for generating NITRE.

BLOW-PIPE is a very important article of CHEMICAL APPARATUS. (See the Appendix.)

BLUE (Mountain) is a beautiful ore, a native *Carbonat* of COPPER.

BLUE (Pruſſian). See PRUSSIAN *Blue*.

BLUE (Saxon) is a ſolution of INDIGO in ſulphuric acid, much uſed in ſome kinds of dyeing, eſpecially of ſilk.

[k] Fourcroy. [l] Marſhall, Rural Econ.

BOG-ORE of iron is a native mixed carbonat and phoſphat of iron. See IRON.

BOLE.[a] *Bol*, Brochant and Emmerling. *Argilla bolus*, Werner.

The colour of this mineral is generally an obſcure iſabella yellow, or reddiſh or whitiſh brown, it is alſo met with of a greyiſh yellow or fleſh-red, and marked with black ſpots or dendritical figures. It is generally maſſive, ſeldom diſſeminated. It poſſeſſes a ſlight glimmering internal luſtre. Its fracture is perfectly conchoidal. It flies when broken into irregular ſharp-edged fragments. The dark coloured varieties are opake, the lighter coloured are more or leſs tranſlucid. It has a greaſy feel, adheres ſtrongly to the tongue, gives a ſhining ſtreak, is ſoft and eaſily frangible. Sp. gr. 1.4 to 2.0.

When put into water it abſorbs a portion with great eagerneſs, and then with a very ſenſible crackling noiſe breaks down into ſmall fragments, but is not reduced to an impalpable powder. When finely pulverized and diffuſed through boiling water, it remains a much ſhorter time ſuſpended in this fluid than any of the plaſtic clays are, and is totally ſeparable by filtration.

When expoſed to the action of the blowpipe it turns black and melts without addition into a porus, greeniſh-grey ſlag.

According to Bergman[b] the Lemnian bole contains

47.0	ſiliceous powder,
5.4	carbonated lime,
6.2	carbonated magneſia,
21.0	alumine,
5.4	oxyd of iron,
17.0	water and volatile matter.
102.0	

Bole occurs in beds of wakke at Strigau in Sileſia, and in baſalt at Scheibenberg in Saxony. It is alſo found in Tuſcany and Sienna in Italy, and in the iſland Lemnos in the Archipelago.

The only uſe of bole at preſent is as a coarſe red pigment; for which purpoſe it is calcined and levigated, and is vended in Germany under the names of Berlin and Engliſh red. Anciently it uſed to be an eſteemed article in the materia medica, for which purpoſe not only the true bole but many of the bolar earths and clayey marls were made up into ſmall cakes impreſſed on one ſide with the figure of a goat, or the ſeal of the governor of Lemnos, &c. and kept in the druggiſts' ſhops under the general name of *Terræ ſigillatæ*.

BOLOGNIAN *Stone*. A ſpecies of native ſulphat of barytes, from which a remarkable pyrophorus, or phoſphoreſcent ſubſtance is prepared. See PHOSPHORI *(Solar)* and HEAVY-SPAR.

BOLT-HEAD an article of chemical apparatus, is a globular matraſs with a long narrow neck. See the Appendix.

BOMBIC *Acid*. The natural juices of ſome inſects have been found to contain an uncombined acid of no inconſiderable ſtrength. One of theſe is the ſilk-worm. This was detected by Chauſſier, from the circumſtance of blue paper having been accidentally laid near theſe inſects while changing to the chryſalis-ſtate, being found covered with red ſpots, as if drops of acid had been ſpilled upon it.

To prepare it he bruiſed 15 ounces of ſilk-worm chryſalides in a mortar, and by expreſſion through a linen cloth he obtained 9 ounces of a thick yellowiſh juice, ſtrongly acid, but mixed with much animal mucilage and other matter. As this would ſoon putrify and deſtroy the acid, he added firſt 2 ounces of alcohol and filtered the liquor, then added more alcohol as long as any precipitate was formed. This precipitate was animal mucilage and other impurities, inſoluble in alcohol whilſt the acid remained in ſolution with the ſpirit. A ſhorter and better method is ſimply to infuſe the chryſalides in alcohol, which readily extracts the acid, becoming thereby of an orange colour, and afterwards this may be concentrated by a gentle heat, which will evaporate moſt of the ſpirit and leave the acid pure after filtration.

The bombic acid will unite with the alkalies and with many of the metals, forming ſalts, called in the modern nomenclature *bombiats*, but which are altogether unknown.

BORACIC ACID.[c] *Sedative Salt. Acide Boracique. Boraxſaure.*

This ſubſtance was firſt diſcovered in 1702, by Homberg, who by heating together in a ſubliming veſſel a mixture of borax and ſulphat of iron obtained a white cryſtalline ſalt, which from its ſuppoſed medical qualities he named *volatile narcotic ſalt of vitriol*, or *ſedative ſalt*, imagining that it was produced from the vitriol. Lemery the ſon, however obtained the ſame ſalt ſoon after by treating borax with the ſulphuric, nitrous, and muriatic acids, thus ſhowing that

[a] Emmerling, Brochant, Jameſon. [b] Bergman's Eſſ.

[c] Leonhardi's Macquer. Gren's Syſt. Handb. Beaumé Chim. Exper. Fourcroy. Encyclop. Method art. Acide Boracin.

the vitriol in Homberg's experiment acted only in conſequence of the acid which it contained. In 1788, Weſtrumb publiſhed his diſcovery of the preſence of boracic acid in a mineral, which on that account has ſince been called *boracite*; and about the ſame time M. Hoëfer found this acid in the water of ſome of the Tuſcan lakes. The water of lake Cherchiajo, in the territory of Sienna, which is ſupplied from a boiling hot ſpring of a ſulphureous odour, contains about $\frac{1}{100}$ of boracic acid: that of the lake of Caſtel Nuovo contains a little more than $\frac{1}{170}$; and a hot ſpring near Saſſo, in Sienna, depoſits a concrete ſalt, conſiſting of boracic acid mixed with about $\frac{1}{3}$ of ſulphat of manganeſe.[d] The term boracic acid was appropriated to this ſalt by Lavoiſier and his aſſociates at the general reformation of the chemical nomenclature.

Boracic acid may be prepared in two ways; either by direct ſublimation or precipitation. The beſt method of obtaining it, according to the former of theſe proceſſes, is the following. Take two parts of purified borax reduced to a fine powder, and mix them in a glaſs alembic with one part of ſulphuric acid, previouſly diluted with an equal weight of water: on the application of a gentle heat the borax will diſſolve, and at a boiling temperature there will firſt riſe an acidulous water, and afterwards, when the maſs in the alembic begins to grow thick, a light white glittering micaceous ſalt will collect in the capital, which is the boracic acid. As this ſalt ſublimes only while the laſt portions of moiſture are evaporating, it is neceſſary to return back repeatedly the acidulous water upon the maſs in the alembic, in order to obtain the whole of the boracic acid; but this being a tedious operation and generally terminating in the fracture of the alembic, is at preſent but little practiſed.

The moſt expeditious and economical way of preparing the boracic acid is by precipitation. For this purpoſe take a boiling hot ſaturated ſolution of purified borax in water, and add to it by a little at a time ſo much ſulphuric acid as to make the ſolution ſlightly acidulous. The liquor when cold will be found to have depoſited a conſiderable quantity of thin cryſtalline plates of boracic acid, and more may be obtained by ſucceſſive evaporation and cooling, till cryſtals of ſulphated ſoda begin to make their appearance. The ſulphuric acid is on ſeveral accounts preferable to any other for the decompoſition of the borax; yet the nitric, muriatic, or even the acetous acids may be made uſe of.

[d] Klaproth, Analyt. Eſs. ii. p. 75.

The proportion of acid obtained by precipitation amounts, according to Beaumé, to nearly one half of the borax made uſe of; and it is this kind of boracic acid that has been employed by moſt chemiſts in their experiments on this ſubſtance. The precipitated acid is however by no means pure. Cadet[e] has clearly ſhown that after repeated lotions in cold water, and even ſolutions in alcohol, it retains a very ſenſible portion of the acid by which it has been precipitated; by which mixture its own properties are in many reſpects modified and altered. Beaumé's analyſis renders it alſo probable that beſides the precipitant the common boracic acid contains ſoda, and is perhaps only borat of ſoda with exceſs of acid, as borax is borat of ſoda with exceſs of alkali. 100 parts of boracic acid, according to this able chemiſt, contain

56	boracic acid,
14	an impure unſublimable ſalt,
30	water of cryſtallization.
100	

The moſt accurate, and upon the whole the moſt expeditious way of obtaining boracic acid in a ſtate ſufficiently pure for chemical experiment, is to decompoſe the borax by muriatic acid, and then fuſe the precipitated ſalt in a ſilver crucible in order to drive off the portion of muriatic acid with which it is combined: the vitreous boracic acid being then finely pulverized, muſt be put into an alembic with water, and pure ſublimed boracic acid will be obtained much more eaſily than by heating together borax and ſulphuric acid.

Sublimed boracic acid is in the form of very minute thin plates, with a ſhining ſilvery luſtre and remarkably voluminous in proportion to its weight. The cryſtallized acid has the ſame general appearance, only it is in larger plates and of conſiderably greater ſpecific gravity. Pure boracic acid has not yet been the ſubject of any recorded experiments; the properties of the precipitated acidulous ſalt are the following.

Its taſte is ſlightly ſubſaline; it reddens ſyrup of violets but exhibits very feeble acid characters: if prepared by the acetous, nitric or muriatic acids it lets them go in a vaporous or gaſſeous ſtate when diſtilled with ſulphuric acid. It is very ſparingly ſoluble in cold water, and a pound troy of this fluid, even when boiling, will take up no more than 150 grains: as the water cools, it depoſits in cryſtalline plates nearly the whole of the acid that it had diſſolved. Alcohol takes

[e] Mem. Acad. 1780, p. 583.

up a larger quantity of this ſalt than water does, and burns in conſequence with a green flame; hence boracic acid has by ſome chemiſts been ſuppoſed to contain copper. But if a piece of paper is dipped in the alcoholic ſolution and then dried, it will burn with a deep yellow flame, it is therefore obvious that the green tinge in queſtion is only cauſed by a mixture of the yellow flame of the boracic acid with the blue one of the alcohol. Other ſubſtances which tinge flame of a blue colour, ſuch as ſulphur and common ſalt, when mixed with boracic acid burn green.

When boracic acid is heated to redneſs in a ſilver crucible, it becomes firſt of a paſty conſiſtence and then melts into a tenacious glaſs, perfectly colourleſs and tranſparent: by expoſure to the air this glaſs becomes opaleſcent, but does not undergo any other change. It is ſoluble in hot water, and may be obtained by cooling, in the ſtate of cryſtalline plates as before. When fuſed in an earthen crucible it diſſolves ſome of the earth and forms a ſemi-tranſparent glaſs conſiderably leſs fuſible than the pure acid; which when diſſolved in water and evaporated becomes a gelatinous maſs, ſuperficially covered with a few cryſtals of boracic acid. Neither the oxygenizing nor deoxygenizing proceſſes appear to have the ſmalleſt effect on this acid, and all attempts to decompoſe it, numerous as they have been, have not been attended with the ſmalleſt ſucceſs.

Boracic acid unites in the moiſt way with the cauſtic alkalies, and by double affinity with the earths and metallic oxyds, except gold, platina, ſilver, biſmuth and manganeſe. It is ſaid to decompoſe nitrat of mercury by ſingle affinity; but this is in all probability owing to the muriatic or ſulphuric acid with which it is combined, for if it is prepared with nitric acid no ſuch effect takes place.[f] The order of its attractions in the humid way, according to Bergman, is, lime, barytes, magneſia, potaſh, ſoda, ammonia, zinc, iron, lead, tin, cobalt, copper, nickel, mercury and alumine. In ſolution it yields theſe baſes to almoſt every other acid.

In the dry way boracic acid unites with the alkaline earths, phoſphat of lime, the fixed alkalies, the metallic oxyds, ſilex and alumine; and on account of its great fixity and fuſibility it diſlodges all the acids, except the phoſphoric, from their combinations.

It has no effect on the reſins: but a ſaturated ſolution of it in boiling water is miſcible with the gum-reſins and oils into an imperfect ſapo-naceous compound. It is alſo ſaid to retard the coagulation of milk.

The combinations of boracic acid with the ſalifiable baſes are called *Borats*, a genus of ſalts hitherto very little known. Thoſe, concerning which we are not wholly ignorant, are the following.

Borat of Potash.

This ſalt is prepared by boiling boracic acid in a ſolution of cauſtic potaſh, either to exact ſaturation or ſo as to leave a ſlight exceſs of alkali; in this latter caſe it cryſtallizes in pretty large four-ſided priſms, has a ſub-alkaline taſte, is permanent in the air, and when expoſed to heat firſt ſwells and foams and then runs into a clear glaſs.

Sub-borat of Soda. Borax.

Borax is a ſaline ſubſtance that has hitherto been found only in Tibet.[g] It is procured from a lake ſituated among the mountains, fifteen days journey from Tiſoolumbo the capital, and entirely ſupplied by ſprings, no ſtreams either falling into or flowing from it. The water has a ſalt taſte and contains both borax and common ſalt, and on account of its elevated ſituation is frozen for a great part of the year. The edges and ſhallows of the lake are covered with a ſtratum of borax which is dug up in conſiderable maſſes, and the holes thus made are gradually filled by a freſh depoſition: from the deeper parts of the lake common ſalt is procured. The borax in its rough ſtate is called tincal, and is brought to Europe in the form of a browniſh-grey impure amorphous ſalt, or in detached cryſtals about an inch in length, of a pale greeniſh hue, and in the form of compreſſed hexahedral priſms.

The purification of borax is an art which was firſt diſcovered by the Venetians, afterwards paſſed to the Dutch, and is now practiſed in great perfection by ſome Engliſh chemiſts. The proceſs is as yet kept a ſecret, but in all probability conſiſts of calcination, ſolution and cryſtallization. The crude borax is often covered with an oily or greaſy matter to prevent it from effloreſcing, and on this account is not eaſily acted on by hot water. It appears however that by expoſing the tincal to a calcining heat lower than its point of fuſion, the greaſe may be burnt off and the other inflammable impurities got rid of; the reſidue being then reduced to a fine powder and digeſted in boiling water, the ſaline parts will be diſſolved, leaving moſt of the impurities behind.

Borax when quite pure is in colourleſs cryſ-

[f] Cadet in Mem. Acad. 1780, p. 583.

[g] Phil. Tranſ. lxxix. p. 97.

talline maſſes, very ſlightly efflorescent on expoſure to the air. Its ſpecific gravity, according to Kirwan, is 1.74. Its taſte is ſomewhat ſweetiſh and ſenſibly alkaline: it turns ſyrup of violets green, ſhewing therefore an exceſs of alkali in its compoſition. It contains by Kirwan's analyſis

34 boracic acid,
17 ſoda,
47 water of cryſtallization.

98

Borax when expoſed to a dry heat ſpeedily diſſolves in its water of cryſtallization, it then, as the moiſture evaporates, becomes of an opake white colour, and a voluminous ſpungy texture like burnt alum. If the heat is encreaſed to a moderate redneſs it liquefies, and when cool appears as a colourleſs tranſparent glaſs. If poured out of the crucible in order to cool, it ſhould be transferred as ſoon as it becomes ſolid to a covered baſon or other proper veſſel, for it always cracks and flies to pieces before it grows cold. Borax when thus fuſed is called glaſs of borax. By expoſure to the air it acquires the appearance of chalcedony on account of the partial efflorescence that it undergoes. If made in a ſilver crucible, or if *haſtily* melted in an earthen one, it is perfectly reſoluble in water, but when kept fluid for a long time in a common crucible it diſſolves a portion of the earth of the veſſel and becomes little if at all ſoluble in water.

Cryſtallized borax requires twelve parts of water at the common temperature for its ſolution, but only ſix parts of boiling water; it therefore depoſits cryſtals by mere cooling.

Borax is decompoſable by all the mineral and vegetable acids when added to exceſs, the boracic acid being ſeparated and the ſoda uniting with the other acid; but if only the *exceſs* of ſoda is combined with the other acid, the whole by evaporation and cooling forms a confuſedly cryſtallized maſs, in which the three ingredients appear to be in mutual combination. Borax will alſo diſſolve and combine with nearly half its weight of boracic acid, forming *borat of ſoda*. In this ſalt the acid and alkaline parts compleatly ſaturate each other, ſo that it produces no change on ſyrup of violets, neither does it poſſeſs any longer an alkaline taſte: it does not effloreſce like common borax, nor are the forms of its cryſtals the ſame. The affinity of ſoda for boracic acid is not ſo great as that of barytes, ſtrontian, lime and magneſia; theſe alkaline earths therefore decompoſe borax, the pure alkali remaining in ſolution, and the earthy borats forming pulverulent inſoluble ſalts. Potaſh is alſo capable of decompoſing borax, but borat of potaſh being very ſoluble in ſoda, no precipitation takes place. Silex and alumine combine in the dry way with borax, the former into a tranſparent, the latter into an opake glaſs. If the ingredients are in nearly equal proportions the glaſs is inſoluble in the mineral acids, but if a conſiderable exceſs of borax is employed, the reſult is a ſoluble glaſs. Of this circumſtance Mr. Chenevix has ingeniouſly taken advantage, by ſubſtituting borax for cauſtic potaſh in the analyſis of the more refractory ſtony compounds, the uſe of the former ſalt being on many accounts much more convenient than that of the latter. Borax will alſo diſſolve moſt of the metallic oxyds, receiving from each of them peculiar tinges of colour.

The uſes of borax are conſiderable: it is employed in the laboratory as a very active flux, and as producing a more perfectly limpid fuſion than any other ſubſtance. For the ſame reaſon it is an ingredient in ſome of the finer kinds of glaſs; though its dearneſs prevents it from being employed ſo often as it otherwiſe might be to great advantage. Borax is alſo highly uſeful to the jewellers and goldſmiths as a flux for the ſolder by which pieces of gold and ſilver are cemented together; and in the Eaſt Indies it is employed in the moiſt way as a ſolvent for gum Lac.

Borat of Ammonia.

Boracic acid digeſted with liquid ammonia depoſits ſmall rhomboidal octahedrons of a ſharp and ſomewhat urinous taſte. This ſalt changes the colour of ſyrup of violets green, ſhewing an exceſs of alkali: it undergoes no action from the air except a ſlight ſuperficial efflorescence. When expoſed to a melting heat, according to Wenzel, the ammonia flies off and the acid vitrifies, except a ſmall portion that is volatilized with the water of cryſtallization. According however to Laſſone, this ſalt melts entire into a greyiſh glaſs, which by ſolution in water gives the ſame kind of cryſtals as before its fuſion. The fixed alkalies, both in the moiſt and dry way decompoſe it by combining with the acid.

Borat of Lime.

A ſolution of boracic acid mixed with lime water becomes immediately turbid, and after a while a pulverulent precipitate falls down, which is borat of lime. It is fuſible at a full red heat into a white ſemitranſparent glaſs. Two parts

of chalk with one of ſedative ſalt, give by fuſion in an earthen crucible a very hard yellow glaſs which ſtrikes fire plentifully with ſteel: if the proportions are inverted, the reſult is a ſomewhat ſofter glaſs which often runs through the crucible. Three parts of earth of bones with one of ſedative ſalt, gives a white porcellanous maſs of extreme hardneſs. [h]

Borat of Magnesia.

Magneſia by long digeſtion with boracic acid is ſlowly diſſolved, and the liquor by cooling depoſits cryſtalline grains of borat of magneſia, which are exceedingly difficult of ſolution in water. Paper dipped in a ſolution of this ſalt and afterwards dried, burns with a yellowiſh-green flame. Alcohol in a great meaſure decompoſes it, taking up the acid and leaving the earth behind. According to Achard [i] one part of ſedative ſalt fuſed with two parts of carbonated magneſia affords a yellow porous vitreſcent maſs, which corrodes the crucible and gives fire with ſteel.

Borat of Alumine.

If newly precipitated undried earth of alum is digeſted with boracic acid, and the clear ſolution then evaporated, there will be depoſited minute cryſtals mixed with a gummy ſubſtance of a remarkably ſtyptic taſte. This gummy matter appears to be chiefly borat of alumine. It is decompoſed in the moiſt way by magneſia, lime and the alkalies, and by a melting heat runs into a glaſs. One part of dried earth of alum mixed with four parts of ſedative ſalt, by expoſure to a ſtrong heat underwent little or no alteration, except that the inſide of the crucible was ſtudded with ſmall white very brilliant cryſtals. [k]

BORAX. (See the preceding article.)

BORACITE. [l] *Borazit, Wurfelſtein. Magneſie boratée* of Hauy.

The colour of this mineral is yellowiſh, ſmoak or aſh-grey, paſſing into greyiſh or greeniſh-white. It occurs in ſmall cubic cryſtals truncated on the angles. The cryſtals are for the moſt part opake, ſome are ſemitranſparent, and a few of the ſmalleſt are entirely tranſparent. Their luſtre internally is conſiderable and of the vitreous kind. The fracture is ſmall and flat conchoidal, paſſing into uneven and ſplintery. The cryſtals are often more or leſs corroded, and then are eaſily pulverizable, but when perfect they are hard enough to give briſk and lively ſparks with ſteel. Sp. gr. 2.56.

Boracite, when expoſed to a full red heat, becomes opake and loſes about ½ per cent. of its weight, but undergoes no other change. When intenſely heated in a clay crucible, it runs into a yellowiſh glaſs. It is entirely though with difficulty ſoluble in muriatic acid by long digeſtion. According to the analyſis of Weſtrumb it conſiſts of

68	boracic acid,
13.5	magneſia,
11.	lime,
1.	alumine
0.75	oxyd of iron,
2.	ſilex
96.25	

Some later experiments however of Vauquelin make the proportion of lime to be much ſmaller, and it appears probable that the only eſſential ingredients of this mineral are magneſia and boracic acid.

Boracite is found near Luneburg in the duchy of Brunſwick, lining the ſides of a vein in a hill of gypſum. The cryſtals from their ſhape were known in the neighbourhood by the name of wurfelſpath or cubic ſpar, and were ſuppoſed by ſome mineralogiſts to be a variety of quartz. The preſence of boracic acid in them was not ſuſpected till their analyſis by Weſtrumb.

BONE. This important ſubſtance is found to compoſe a neceſſary part of the organized ſtructure of all the mammalia, of birds, of the greater number of fiſhes, ſome of the reptiles, and the oviparous quadrupeds. In all, its uſe is to give firmneſs and ſupport to the body, and to ſupply an unyielding fulcrum for the origin and inſertion of moſt of the muſcles ſubſervient to locomotion. The ſame ſubſtance, a little modified in the proportion of its conſtituent parts, alſo furniſhes many of the natural weapons of defence, as the teeth, tuſks of all kinds, and the ſolid horns, ſuch as the antlers of the ſtag or elk. On the whole, ſo great a ſimilarity of compoſition is found in all theſe varieties of bone that a general deſcription may firſt be given, and the bone of any quadruped (of the ox for inſtance) may be taken as an example of the whole genus.

It may be premiſed that there are at leaſt two other great claſſes of organs ſerving for aſſault or defence, deſcribed in their proper places, one, the cuticular organs, nails, claws, and hoofs, which cloſely partake of the chemical nature of the ſofter and lighter Horns; and the other, the vaſt variety of cruſtaceous and teſtaceous coverings or calcareous habitations of

[h] Achard, Mem. de l'Acad. de Berlin, 1799, p. 86. [i] Ditto. [k] Ditto. [l] Emmerling. Hauy. An. de Chim. ii.

inſects, chiefly marine, which belong to the extenſive chemical genus of SHELL.

Bone when firſt taken from the animal is moiſt and greaſy to the feel, and if cylindrical it contains within its cavity a peculiar fat called *marrow*. When this is ſeparated and the bone cleanſed and expoſed to a dry air it gradually dries, becomes more brittle and whiter, and under theſe circumſtances may be kept for a great length of time without any further ſpontaneous change.

Bone, though to appearance quite dry and hard, is however eſſentially compoſed of certain *ſoft parts*, and of an earth or rather *earthy ſalt* beſides other conſtituents of leſs importance, and the ſeparation of theſe leading component parts is to be effected very compleatly by the proper uſe of water, the ſimpleſt and leaſt exceptionable of all chemical reagents. It has long been known to common obſervation that raſped bone (hartſhorn ſhavings for inſtance) boiled in water, furniſh a good deal of clear ſtrong jelly, and that uncooked bones chopped in pieces and added to the other materials for ſoup aſſiſt much during the boiling in giving richneſs and thickneſs to the liquor.

By the valuable experiments of Pelletier on procuring glue from bones, [a] and thoſe of Prouſt [b] on the extended uſe of bone for human nutriment, the analyſis by water has been carried to its greateſt extent.

Cold water has very little action on bone, except in diſpoſing it after a conſiderable time to a degree of putrefaction. When raw bones chopped in ſmall pieces are put into ſcalding water, the firſt effect is to diſengage a conſiderable quantity of oil (not marrow but a fat naturally combined with the ſubſtance of bone) which melts out by the heat and riſes to the ſurface of the water, concreting when cold into a ſuetty maſs which readily ſeparates from the water. In this way, by only a quarter of an hour's boiling, Prouſt obtained from the knuckle and other joint bones of beef no leſs than one-fourth of their weight of this ſuet, which was fine, white, and inſipid. The ſhank part of the bone and the heavy flat bones yielded leſs of this fat.

Anatomiſts alſo conſtantly find this ſame oily matter ſweating out of the bones of the ſkeleton, eſpecially about the joint heads where the bones are lighter and much more open in their texture, and it requires long and very careful preparation entirely to get rid of it.

If the above chopped bones, freed from their oil, are now ground down to a pretty fine paſte, and again boiled with about ten times their weight of water for ſome hours, till nearly half the water is waſted, the remaining liquor will be of the conſiſtence of thick ſoup, and when cold will concrete into a fine clear yellowiſh ſtiff jelly, nearly about the conſiſtence that would be produced by diſſolving one ounce of glue in thirty-one ounces of water, and extremely palatable and nutritious. At the bottom of the veſſel the powdered bones are now found, much reduced in bulk and with little coheſion when rubbed between the fingers. The clear jelly, which ſhould be poured off when hot, if further evaporated ſlowly towards dryneſs, and afterwards fully dried as in the manufacture of GLUE, affords a very firm good glue applicable to a number of purpoſes.

It is to be obſerved that any kind of bone however dry (if uncooked) yields abundance of this jelly by powerful boiling with water. So Pelletier obtained a pound of ſtrong glue from 6 pounds of button-mold ſhavings, and 9½ pounds of glue from 50 pounds of ivory ſhavings. Some jelly has been obtained even from bones kept for many centuries in cemeteries, provided they have been preſerved above ground and not much expoſed to moiſture, ſo that this conſtituent part is very ſlow of decay.

Scarcely any boiling in *open* veſſels however can totally ſeparate the gelatin and perhaps the oil from the earth of bones, for in the above experiments the bony paſte after repeated and long boiling was not abſolutely dry and friable to the touch but had ſomewhat of a ſoapy feel, and when burned ſhewed ſome remains of the ſoft parts. But a much higher heat than the boiling point given to the water will completely produce this ſeparation, and this is to be done in *Papin's digeſter*, as the inventor of this inſtrument actually found.

The gelly obtained in this way acquires however ſomewhat of a burnt taſte and is leſs palatable, but the earthy reſidue is now perfectly crumbly and harſh to the fingers, and contains ſcarcely any trace of gelatin or animal fat.

Another *ſoft part* ſtill remains to be mentioned. The diſcovery of it we owe to Mr. Hatchett, whoſe admirable experiments on the variety of hard animal organs, ſerving for ſupport, protection and covering, have formed a moſt important addition to chemical phyſiology. [c] When freſh bone is immerſed in any acid (the dilute muriatic or nitrous are beſt) a very ſlight effervescence is perceived, and it gradually

[a] Memoirs, tom. ii. [b] Journ. de Phyſ. tom. 53. [c] Phil. Tranſ. for 1799 and 1800.

becomes ſoft, flexible, and porous, but retaining its original ſhape. The acid at the ſame time ſlowly diſſolves out the gelatin (becoming thereby ſomewhat viſcid and yellow) and alſo all the earthy part, ſo that at laſt nothing is left but an open reticulated cartilage or ſpongy cellular membrane. If the bone has been previouſly boiled the experiment will ſucceed as well, only there will remain leſs gelatin for the acid to diſſolve, being already chiefly extracted by the water.

This ſpongy cartilage is eſſential to the conſtitution of all organized bones, and alſo of all ſhells and other hard coverings of animals, and it is the part firſt formed by nature, being as it were the outline or ſketch of the bone, which afterwards receives ſolidity and ſtrength by the gradual depoſition of the earthy part. This rudimental cartilage is moſt conſpicuous in the fœtal ſtate and in animals juſt born, whoſe bones are yet ſoft and flexible, but gradually acquire hardneſs and denſity by the increaſe of the earthy part in the proceſs of oſſification. Bony cartilage being inſoluble both in water and in weak acids is therefore ſeparable from the gelatin by the former menſtruum, and from the earthy parts by the latter, but it cannot be readily exhibited in any other way than that above mentioned. Mr. Hatchett has found it to reſemble coagulated *albumen*, and to differ from gelatin by the following deciſive marks.

When dry it is ſemitranſparent like horn and more or leſs brittle. In this ſtate it ſo much reſiſts the action of water that it may be boiled with this fluid for many days without ſenſibly diminiſhing; whereas the gelatin even of the hardeſt bones, as we have ſeen, is readily extracted by this fluid. The high heat of Papin's digeſter will however enable water to diſſolve even coagulated albumen.

It is ſcarcely acted on by any acid if dilute, and without the aſſiſtance of heat, though by long maceration it becomes at laſt ſomewhat ſoftened, and then diſſolves in ammonia making a blood-red liquor. But if nitric acid is heated on this albuminous cartilage it is rapidly diſſolved with diſcharge of much nitrous gas.

With cauſtic fixed alkali it is readily diſſolved into a perfect animal ſoap, and during the proceſs much ammonia is given out. Acids again ſeparate the albumen from this ſoap unchanged. This character is much depended on by Mr. Hatchett as an argument for its affinity with albumen and difference from gelatin.

It is alſo extremely ſlow of putrefaction, remaining long unaltered even in warm and moiſt ſituations, and in this too it ſtrongly reſembles coagulated albumen.

We may therefore enumerate as the *ſoft parts* of bone, gelatin, oil, albumen, and water.

A Swediſh chemiſt, Gahn, was the firſt who diſcovered the true nature of the *earth* of bones. This earth is produced by burning bones of any kind in open veſſels, or in the large way in the open air, till every thing volatile and inflammable is diſſipated; and there then remains a hard porous white earthy ſubſtance, retaining the ſhape and ſize of the original bone, and generally amounting to from one-half to a third of its weight. This earth is eaſily reduced to powder, and ſuffers the moſt intenſe heat without further change. It is found to conſiſt almoſt entirely of PHOSPHAT *of lime, with exceſs of lime*, or what is elegantly termed, according to Dr. Thompſon's ſyſtem of nomenclature, *Subphoſphat of lime*, mixed with a ſmall quantity of *ſulphat* and of *carbonat of lime*. Meſſrs. Fourcroy and Vauquelin have likewiſe detected a ſmall portion of *phoſphat of magneſia* in the earth of the bones of all claſſes of animals except the human.

Many of the chemical properties of the earth of bone will be deſcribed under the article PHOSPHAT *of lime* and PHOSPHORUS, for the preparation of which laſt it is peculiarly convenient. For the analyſis of bone the following particulars ſhould be noticed.

Phoſphat of lime exiſts in two ſtates, in one with an exceſs of calcareous baſe as in the bone-aſh, in the other with exceſs of phoſphoric acid. When ſulphuric acid is added to the bone-aſh, only a partial decompoſition takes place, and the phoſphat by giving up a part of its lime to the ſulphuric acid is changed to the *acidulous phoſphat of lime*. This laſt, when dried and heated red hot, runs into a greyiſh white ſemiopake glaſs, and when ſtrongly heated with charcoal the exceſs of acid is decompoſed thereby, and the product is *phoſphorus*, whilſt the phoſphat of lime, now deprived of its exceſs of acid, remains unchanged.

Phoſphat of lime in any ſtate is ſoluble with extreme eaſe in every acid, even by the carbonic when ſuſpended in water and expoſed to a ſtream of this acid gas; but it does not appear to be at all decompoſed by any acid whoſe calcareous ſalt is a ſoluble one. Thus the nitric, muriatic and acetous acids, when digeſted with the earth of bones, ſimply diſſolve the phoſphat of lime, and again let it fall unchanged on the addition of any alkali, cauſtic or carbonated; and therefore the precipitate even

with the carbonated alkalies is not a carbonat of lime but ſimply the original phoſphat, and will not effervеſce with acids. This is a convenient circumſtance in analyſis, for if the phoſphat of lime to be examined is mixed with carbonat of lime (as is the caſe in ſmall quantity in bone-aſh, and is indicated by a ſlight effervеſcence with acids) both are diſſolved by the acid, and then cauſtic ammonia will precipitate only the phoſphat of lime, and afterwards the lime belonging to the carbonat will be precipitated in a carbonated ſtate by the addition of any carbonated alkali. The nitrous acid moderately diluted is a very convenient menſtruum in the analyſis of bone.

The phoſphoric acid is indicated in another way. All the phoſphoric alkaline and earthy ſalts, even the phoſphat of lime, are completely decompoſed by the ſalts of lead and mercury. Thus if nitrat or acetite of lead is dropped into a ſolution of phoſphat of lime, all the phoſphoric acid is ſeparated and forms by double decompoſition a precipitate of phoſphat of lead, which is readily known by the following characters. When heated by the blowpipe on charcoal, it melts eaſily into a pearl-white globule, which immediately on diſcontinuing the flame cools into a button of a polyhedral form; but if the flame is continued, the phoſphoric acid is gradually decompoſed, and burns off with a luminous vapour ſmelling of phoſphorus, and at laſt a globule of pure lead is left. Phoſphat of mercury is precipitated as a white powder, which before the blowpipe on charcoal melts with effervеſcence and a green flame into a yellowiſh glaſs: by continuing the heat the mercury is volatilized firſt, and may be condenſed in its metallic ſtate on a plate of copper held over the vapor; the phoſphoric acid then burns off into phoſphorus as above mentioned. Phoſphat of lead dried at a low red heat contains 22.5 per cent. of phoſphoric acid.[d] If ſulphuric acid in any combination ſhould happen to be preſent in the ſolution of phoſphat of lime, it will alſo be decompoſed by the nitrat of lead, and the precipitate will therefore be a mixture of ſulphat and phoſphat of lead. Theſe are ſeparable by dilute nitric acid, which will diſſolve the phoſphat but not the ſulphat. This teſt is alſo of uſe to diſtinguiſh and ſeparate the ſulphat from the phoſphat of lime, the latter being ſoluble in the acid, but not the former.

It has been mentioned that Meſſrs. Fourcroy and Vauquelin have detected a ſmall portion of phoſphat of magneſia in the bones of quadrupeds and alſo of moſt other animals, except the human bone.[e] This earthy ſalt is thus obtained: take calcined ox or horſe bones in fine powder, treat them with an equal weight of ſulphuric acid and mix thoroughly. After five or ſix days dilute the maſs with ten times as much pure water, and ſtrain through a linen cloth, preſſing it at laſt to expel all the liquid, and pour freſh water on the white reſidue, preſs again and add this liquor to the other. Filter this acid liquor, which conſiſts chiefly of phoſphoric acid with acidulous phoſphat of lime, of phoſphat of magneſia combined with ammonia into a triple ſalt, the *ammoniaco-phoſphat of magneſia*, together with ſome ſulphat of lime. Add cauſtic ammonia in exceſs, which will precipitate only the phoſphats of lime and magneſia. Waſh the precipitate with cold water, and boil with a ſolution of pure potaſh, till no further ammoniacal ſmell ariſes. The potaſh has now completely decompoſed the magneſian phoſphat (but not the calcareous, on which none of the alkalies have any notable action) and the magneſia remains uncombined in the alkaline mixture and only mixed with the phoſphat of lime. Waſh out the remaining alkali, and add boiling acetous acid to the reſidue, which will diſſolve the magneſia before it touches the phoſphat of lime. This ſolution of acetite of magneſia treated with carbonat of ſoda and gently boiled gives a precipitate of carbonat of magneſia, which, if neceſſary, may be ſeparated from any adhering lime by ſolution in ſulphuric acid and cryſtallization.

By a number of comparative experiments the above mentioned chemiſts found that the calcined earth of ox-bones contained about $\frac{1}{10}$ of its weight of phoſphat of magneſia (amounting to about $\frac{1}{10}$ of the unburnt bone, ſince by calcination it loſes about half its weight); the calcined earth of horſe and ſheep bones gave about $\frac{1}{16}$ of this earthy phoſphat; chicken and fiſh bone nearly the ſame as thoſe of oxen, but there was no appreciable quantity in the human bone.

We may add the conſtituent parts of entire ox bone as given by theſe chemiſts.

Solid gelatin - - -	51.
Phoſphat of lime - -	37.7
Carbonat of lime -	10.
Phoſphat of magneſia	1.3
	100.0

This eſtimate is however imperfect, as no account is taken of the oil, nor of the albumen

[d] Klaproth. [e] An. Chim. tom. 47.

of the membranous cartilage discovered by Mr. Hatchett. The earthy salts are probably accurate, and therefore the quantity of albumen and of oil, whatever they be, must be subtracted from that of the gelatin as here given.

The effect of heat on bones remains to be mentioned, for though the analysis by fire is peculiarly imperfect when animal or vegetable matter is the subject, several products valuable in the arts are furnished by this process. When bone is heated without addition in open air, it first becomes greasy and yellow, and gives out a watery vapour, to which succeeds a thick, dense, fetid smoke, which readily takes fire and burns with a most suffocating smoky ammoniacal smell. After some time it becomes black, brittle and carbonaceous, and if heated too suddenly splits and flies in every direction. At last, when a full red heat has been continued for a certain time, all the coal burns off, and nothing is left but the brittle sonorous white earthy phosphat, which retains the form of the original bone and all the porousness of its texture. This process of burning bones is performed near large towns or where bones are in quantity, for the sake of the white earth or *bone-ash*. For this purpose a large heap of the bones are built up in a kind of regular pile and are kindled on the windward side. When thoroughly lit, and when a few of them get hot enough to give out their oil freely, the heat which is produced is sufficient to continue and compleat the burning without further assistance. A large heap continues many hours on fire before it is entirely calcined.

But several products are wasted in this way, which prove highly valuable when the burning takes place in close vessels and the distillation properly managed. For manufacture it is carried on in iron cylinders, for experiment a coated glass or an earthen retort will answer. When thus heated, bone yields with the first impression a limpid faintly-smelling water, which presently becomes *ammoniacal*, and contains a sensible quantity of carbonat of ammonia. With this (the heat being still gentle) a clear yellowish oil rises, pungent and not ungrateful to the smell. This should be carefully set apart and treated in a way to be presently mentioned. As the heat encreases, this oil continues to come over, but now becomes brown, foul, and at last black, of a consistence encreasing to that of melted pitch, strongly ammoniacal, and at the same time excessively fetid and smoaky. An abundance of gas escapes during this distillation, which is chiefly sulphuretted hydrogen, carburetted hydrogen, and carbonic acid. The condensed liquor in the receiver is both a water and an oil, each of which contains a large quantity of carbonat of ammonia, and the former holds some sebacic and prussic acids in solution. The ammonia is the most valuable part of these products, and is obtained pure by subsequent processes, described under the articles CARBONAT and MURIAT of *ammonia*. If the purer part of the oil is distilled *per se* out of a clean glass retort with only a gentle heat, the first portion of the oil rises much clearer than before, and by repeating this distillation out of clean vessels every time, taking only the first part that comes over, the oil becomes clear and limpid as water, with a very pungent ammoniacal smell, and so volatile as to waste quickly in the open air, or if kept in a bottle loosely corked. It is called from the inventor *Dippel's oil*. Much expofure to light turns it brown, and gives it somewhat of a smoaky smell. It is sometimes used in medicine.

If the distillation of the bones is stopped when the oil comes over very black, they are found drenched in a dark fetid oil, and penetrated with it. If the whole is then urged to redness in a close earthen or iron vessel, till every thing volatile has passed over, the earth of the bones remains so thoroughly impregnated with the fine charcoal of the oil as to be uniformly black throughout, glossy and brittle. When ground to a fine powder, mixed with size and made up into cakes, it forms the common *Ivory-black*, which from its greasy nature readily mixes with oil, and is the material for most of the ordinary black paints and varnishes.

A very fine black of the same kind is formed by charring ivory shavings in close vessels.

Bones are whitened by alternate expofure to wind, and moisture and sun. Salt water seems much to assist in this process, to judge by the extreme whiteness and cleanness of bones found on the sea shore. A previous boiling in a weak alkaline lye will much assist in extracting the natural oil, but this should be used with caution, otherwise the bones will soften and crumble down between the fingers. The oxymuriatic acid has also been applied with success to whitening the surface of bones.

The first action of all acids is to soften bone, in which state it readily absorbs any colouring matter, which sinks deeply into its substance. The bone afterwards hardens, and then will take a good polish.

The metallic solutions are very useful for colouring bone in a very deep and permanent

manner. Thus to give a fine green, diſſolve verdigris in diſtilled vinegar, immerſe the bones in the ſolution, and bury the whole in a dung-hill (cloſing the veſſel well) or by any other gentle warmth for ten or twelve days. The bones are then found of a permanent green and will take a good poliſh. The TURQUOISE ſtone bone is found dyed of a native green by ſome mineral ſolution of copper. A good black is given by the ſolutions of ſilver or lead, or by boiling together equal parts of litharge and quick lime in water, and immerſing the bones in it for ſeveral hours. The colour in theſe is heightened, and the poliſh encreaſed by afterwards boiling them in nut-oil. Bones may alſo be made to take the vegetable dyes by firſt ſmearing them with dilute nitrous acid to open their texture, and then rubbing in the dye for ſome time.

TEETH are formed of an internal bony caſe, coated with a very hard white inorganic matter called the *Enamel*.

When a tooth coated with enamel is immerſed in moderately dilute nitric or muriatic acid, [f] a weak efferveſcence takes place, and the enamel is entirely diſſolved. The bony part is alſo acted on but not compleatly diſſolved, for only the earth is taken up, and a cartilage retaining the ſhape of the tooth remains. In this it exactly reſembles other bones, whilſt the enamel differs from them all in being little elſe than an inorganic coating of phoſphat of lime, not formed by depoſition within the cells of an original cartilage, as in bone, but ſimply by a kind of exſudation or depoſition of this earth on the ſurface of the proper tooth.

When a tooth is immerſed in concentrated ſulphuric acid no action is at firſt perceived, but in about an hour ſmall bubbles ariſe, the roots become blackened, and in twelve hours the enamel burſts, cracks and ſeparates. Nitric and muriatic acids moderately diluted act inſtantly on the tooth with an evolution of ſmall air-bubbles. The cartilage left undiſſolved is flexible, ſemitranſparent, and eaſily divided. Boiling nitric acid acts ſtrongly on the tooth with evolution of carbonic acid and azotic gaſſes. Mr. Pepys [g] found the enamel of the human tooth to contain 78 per cent. of phoſphat of lime and 6 of carbonat of lime. They were ſeparated in the analyſis by adding to the nitrous ſolution, firſt, pure ammonia to precipitate the phoſphat, and afterwards carbonat of ammonia to ſeparate the carbonat of lime. The bone of teeth contained 58 per cent. of the phoſphat and 4 of the carbonat, together with 28 of gelatin dried at 212°. The entire teeth of adults, whoſe ſpecific gravity is 2.272, yielded 64 per cent of phophat of lime, 6 of carbonat of lime, and 20 of gelatin. Some difficulty however riſes in eſtimating theſe proportions exactly, on account of the varying proportion of water according to the heat uſed. In the above analyſis the phoſphat was dried at a red heat, but the carbonat and gelatin at the heat of boiling water.

The uſes of bone in different ſtates are various and important. Its gelatin and fat extracted by water affords a cheap and wholeſome nutriment. Bone itſelf is employed in a thouſand ways, in turnery and a number of mechanical arts; all the refuſe part yields by diſtillation a large quantity of ammonia, the baſis of ſome very extenſive chemical proceſſes; a fine black pigment is made by its combuſtion in cloſe veſſels, and laſtly the reſiduary earth is uſed as a material for cupels or aſſay crucibles, for ſome of the opake white glaſſes, and gives *phoſphorus* and a number of phoſphoric ſalts by its decompoſition. It is therefore on all accounts a moſt intereſting object to the chemiſt and manufacturer.

BOVEY COAL. See COAL.

BOYLE's *Fuming Liquor* is the hydroſulphuret of ammonia formed by diſtillation. See SULPHURET.

BRAIN. The brain of animals exhibits ſome peculiarities in its chemical analyſis, which, though they throw no light whatever on the explanation of the aſtoniſhing functions of this noble organ, deſerve ſome notice here as a part of animal chemiſtry.

The experiments of modern chemiſts alone require attention, and eſpecially thoſe of Thouret made in 1790, [h] and ſome made by Fourcroy of a ſubſequent date.

Brain in its natural ſtate is a ſoft pulp, with ſomewhat of a ſoapy feel, and little or no ſmell when freſh. Heated moderately, it dries ſimply by the loſs of water, ſhrinks to about a fourth of its bulk, and then becomes a browniſh-green, thick, tenacious maſs. When dried as fully as poſſible without decompoſition, it becomes ſolid, and breaks under the fingers like old cheeſe. If this is ſtrongly heated in a crucible it gives out ammonia, puffs up, and melts into a black pitchy maſs, and then takes fire and burns with much flame and a thick ſharp ſmoak, leaving a coal difficult to be reduced to aſhes. No naked alkali is left in the aſh, but it ſhews by analyſis

[f] Hatchett. [g] Ph. Mag. vol. xvii. [h] Journ. de Phſ. tom. 32—9.

ſome traces of phoſphat of lime and ſoda. Brain, either in its natural ſtate or gently dried without decompoſition, unites very readily with water by rubbing, and forms an opake uniform emulſive maſs, which froths ſtrongly by agitation, and does not ſeparate from the water by filtration. In this it much reſembles a ſolution of ſoap in water, but differs from the genuine ſoaps in containing no alkali, and hence it will not turn vegetable blues into green.

This emulſion of brain when heated nearly to boiling readily coagulates, and depoſits its contents in white curdy grains. The clear liquid mixed with lime-water gives a precipitate of phoſphat of lime, and hence contains a phoſphated ſalt in ſolution. Acids and all calcareous ſalts added to the cerebral emulſion ſpeedily curdle it. If an acid is employed, the clear liquor remaining after the coagulation contains lime, ſoda and ammonia, all united with the acid.

The nitric acid when dilute only coagulates the cerebral emulſion, but when concentrated it produces an effervescence, with evolution of much azotic gas, violent intumeſcence, heat, and ſubſequent production of nitrous gas, carbonic acid, and ammonia. The reſidue now contains a quantity of oxalic acid, one of the uſual products of the diſtillation of nitric acid with almoſt any animal matter.

Muriatic acid ſimply coagulates the emulſion of brain, without inducing any very ſtriking chemical change.

The cauſtic fixed alkalies even when cold, and much more when hot, unite ſpeedily with brain into a ſoapy maſs, at the ſame time diſengaging much ammonia.

Under the article *Adipocire* was noticed the ſingular action of alcohol and the ſeparation of a peculiar cryſtalline matter. A ſimilar circumſtance occurs here. When brain gently dried over a ſtove, or firſt mixed with water, coagulated by an acid, and the coagulum dried, is digeſted in a boiling heat with about twice its weight of alcohol, a ſolution is effected, which on cooling depoſits a number of yellowiſh white cryſtalline blades. It requires two or three ſucceſſive digeſtions with freſh alcohol entirely to exhauſt this cryſtalline matter. Dried brain loſes in the proceſs about five-eighths of its weight, however on evaporating the alcoholic ſolution, no more than half the above quantity is collected, ſo that the remainder is probably only water intimately combined with the ſubſtance of brain, and not to be expelled by the previous drying. This ſingular cryſtalline matter cruſhes under the finger with a kind of greaſy conſiſtence, is not melted, but only ſoftened in the heat of boiling water; and when further heated it blackens, melts, and gives out a burnt and ammoniacal ſmell. In this reſpect it differs from ſpermaceti, which melts at 140° and cools again unchanged. Adipocire, to which alſo it has been likened, melts unaltered at about 83°. After the alcoholic ſolution of brain has depoſited on cooling all the cryſtalline matter, the ſolution, evaporated, will give more of the ſame, but ſomewhat ſaltiſh and of a ſoapy conſiſtence. This matter may be united with water by rubbing, into a kind of emulſion, which reddens litmus. A long maceration of brain in cold alcohol will diſſolve a ſimilar cryſtalline matter, and hence it is often found depoſited in old ſpirituous anatomical preparations of the brain and nerves.

The ſubſtance of brain bears on the whole a conſiderable reſemblance to albumen reduced to a kind of ſaponaceous ſtate, perhaps by union with ammonia and much water; but the theory of the production of this cryſtalline matter is very obſcure. Though it much reſembles ſpermaceti, adipocire, and ſtill more the cryſtalline matter of *biliary calculi* (deſcribed under that article) it ſomewhat differs from them all, particularly in being difficult of fuſion. Its nature is conſiderably like that of a concrete oil, and hence Thouret was led to endeavour to extract oil from the brain by ſtrong preſſure, but without any ſucceſs.

The ſpontaneous change which brain undergoes by putrefaction, and the very ſlow decompoſition of this organ by ſpontaneous change are very ſingular circumſtances, ſince it is well known to anatomiſts how great a loſs of ſtrength and coheſion in the texture of brain is ſuffered by keeping a very ſhort time after death. Yet this ſame ſubſtance after this firſt change of texture appears to be perhaps the moſt indeſtructible of all the ſoft parts of the animal body. The memorable obſervations of Thouret on the exhumation of the burying ground of Les Innocents, at Paris, put this beyond a doubt. This obſerver remarks, that the bodies contained in this vaſt cemetery were found in different ſtates; the greater number of them (which were thoſe that had lain in heaps in the common receptacles of twelve or fifteen hundred corpſes) were moſtly converted to a kind of whitiſh ſoap, retaining the form of the different parts of the body. In all theſe the brain was in a ſtate of very perfect preſervation, and on opening the ſcull it was found in pretty large

lumps, filling from a third to a fourth of the cavity which it had occupied during life. In this ſtate it was moſtly ſoft, pulpy, breaking down between the fingers like mellow cheeſe, little offenſive to the ſmell, and ſometimes firmer and friable. In theſe globular maſſes, the original form of the brain, the diviſions of its hemiſpheres, and the convoluted texture were ſtill obſervable. Even the natural colour remained, ſo that on cutting it tranſverſely the white medullary part would be diſtinguiſhed from the browner cortical. Even where the period of inhumation had been ſo long as to deſtroy all the viſcera and moſt of the muſcles, the brain ſtill remained.

BRANDSCHIEFER. See CLAY *ſlaty*.

BRANDY. This valuable ſpirit is produced by the diſtillation of wines of all kinds, and properly ſpeaking by no other fermented liquor whatever. Under the article ALCOHOL we mentioned that the purely ſpirituous part of all fermented liquors appeared to be identically the ſame. Brandy, rum, corn ſpirits, &c. being the products of the firſt diſtillation from fermented liquors, and alcohol the purer part of each, ſeparated by a ſubſequent proceſs.

Brandy is prepared in many of the wine countries of Europe, and with particular excellence in many parts of the center and ſouth of France. The neceſſary proceſs is extremely ſimple, being nothing more than a well regulated diſtillation of wine without addition, from ſuitable veſſels, but to alter or improve the colour and flavour various ſubſtances are added to the ſpirit after diſtillation. The manufactory is technically called in France *Brulerie*, and the makers, *Bruleurs d'Eau de Vie*.

Though every wine will give a certain portion of brandy by diſtillation, ſome are much preferable to others. In general the ſtrong heavy wines yield the moſt ſpirit, giving nearly a fourth of good proof ſpirit, whilſt ſome of the light thin wines furniſh no more than about a fifteenth. If the quantity is leſs than a ſixth it will hardly repay the expence of diſtillation.

The diſtilling apparatus is compoſed of three parts, the *alembic* or boiler, the *capital* which fits on the top of the boiler to receive the ſpirituous vapour, and the *ſerpentine* or *worm*, a convoluted pipe fitting to the beak of the alembic and immerſed in a large tub of water, to cool the vapour of the ſpirit, and condenſe it into a liquor which flows out at the bottom.

The alembic[a] is a cylindrical copper boiler, about 30 inches (French) in height, and 24 in diameter, flattened at the bottom to preſent a greater ſurface to the fuel, and drawn out into a neck at the top about 2 inches high, and only 9 or 10 in diameter. It holds about 320 quarts. The capital, which fits on the neck of the alembic has the form nearly of a very flattened cone with the apex downwards, and truncated where it joins the alembic. Its diameter is here of courſe a trifle more than that of the neck of the alembic over which it fits. Above, it is about 7 or 8 inches wide. A tube or beak projects laterally from the lower part of the capital to convey the vapour into the pewter ſerpentine, which makes ſix or ſeven turns before it reaches the bottom of the large tub of water in which it is immerſed. The diameter of the worm is about an inch and a half at the part joining the beak of the ſerpentine, and gradually leſſens to one inch at the bottom. The alembic is built into brick-work, which covers the whole except the bottom, which hangs over the fire, and the neck where it joins the capital. Beneath is the fire, generally wood, encloſed in the uſual manner of fixed boilers, and furniſhed with an aſh-pit and regiſter to damp the fire at pleaſure.

In the diſtillery, the alembic is firſt filled to about five-ſixths of its capacity with wine, and the fire kindled. When the wine nearly boils, the capital is put on, and all the joinings luted with a mixture of clay and aſhes. A thin ſtream of brandy ſoon pours out from the lower end of the worm pipe into a caſk ſet to receive it. The fire at firſt is ſlow, otherwiſe the wine boils up into the capital, and part paſſes into the worm and fouls the ſpirit: and as a general rule, the ſlower the diſtillation the finer and ſtronger is the ſpirit obtained. What firſt comes over is the richeſt in flavour and the ſtrongeſt ſpirit, for as alcohol boils at a much lower temperature than water, the greater part of the ſpirit comes over but little diluted with water; but the liquor gradually decreaſes in ſtrength as the proceſs continues, and at laſt contains ſo little ſpirit as to be entirely uninflammable, and almoſt void of taſte. When this happens, the fire is put out, and the contents left in the alembic, conſiſting of the watery lees of the wine, are thrown away as uſeleſs. The wine is known to be entirely exhauſted of ſpirit, by taking a little of the diſtilled liquor then coming over, putting it on the hot part of the capital and applying a lighted ſtick, if the vapour does not catch fire the liquor is little elſe than water.

As the brandy comes over with a conſtantly

[a] Encycl. Meth. art. Alcool & Diſtillateur Liquoriſte. Beaumé & Roſier in J. de Phyſ. tom. 12 & 18.

decreasing strength, a distinction is always made between the former and the latter part of the product, and the two liquors kept apart. The first is fit for immediate use, the last, which is called *feconde* or *petite eau*, is rediſtilled in the next proceſs. It anſwers to the *feints* of the Britiſh diſtillers. The preciſe time at which the ſecond portion is begun to be collected is arbitrary, and differs in different countries. In ſome countries it is determined by the proportion of ſpirit already obtained to that of the wine put into the alembic; in other places, by a certain ſpecific gravity; in Spain and Portugal, as in rum-making in Jamaica, the ſinking of olive oil in the ſpirit is the eſtabliſhed proof, for the leſs the ſpecific gravity of the ſpirit the greater is its ſtrength. It takes about nine or ten hours to run off the quantity above mentioned.

Brandy is naturally clear and colourleſs as water, for the colour which it has in commerce is given partly by the caſks in which it is kept, but chiefly by certain additions to the ſpirit, ſuch as ſaunders wood, burnt ſugar, &c. and which appear to do neither good nor harm to the quality of the ſpirit.

There are ſeveral ways of judging of the ſtrength of the ſpirit. Many of theſe are mentioned under the article ALCOHOL, which ſee. The dealers alſo judge a good deal of the quality of the ſpirit by the appearance of the bubbles which ariſe when brandy is ſtrongly ſhaken in a phial, by their ſize and degree of permanence. For this purpoſe a ſtrong phial is filled three-quarters with the ſpirit, and ſtrongly knocked againſt the knee to form a froth, and thoſe that are in the habit of examining ſamples put much confidence in this teſt, combined with that of the hydrometer to aſcertain the ſpecific gravity, and the ſmell and taſte. This former teſt however is often fallacious, being liable to be imitated by certain well-known additions.

The ſtrength of the ſpirit of courſe depends on the ſtrength of the wine from which it is made, and the perfection of the fermentation which it has undergone. The quantity of ſaccharine mucilage in the grape-juice, the baſis of fermentation, varies very much according to the ſoil, climate, and ſeaſon, the kind of fruit and time of gathering. In general it is moſt abundant in the warmeſt climates and ſeaſons, and is much encreaſed by lateneſs in gathering the crop. Such wines require a long and compleat fermentation, and then they are rich, full-bodied and ſpirituous. The very ſtrongeſt wines yield about a third of their weight of proof-brandy; on the other hand the weakeſt wines, though well fermented and perfect liquors, give only about a fifteenth. Chaptal ſtates the general average of product from the wines of the ſouth of France and Spain to be about a fourth. [b]

The principal differences in the quality of brandies are *ſtrength* or quantity of alcohol, and *flavour*, which laſt ſeems to depend on ſeveral principles contained in the ſpirit which riſe with it on diſtillation. Beſides this, there are generally ſeveral foreign additions made to it by the manufacturer, which do not belong to the preſent ſubject.

The *empyreuma*, or burnt taſte, is a frequent defect in all diſtilled liquors, and very notably ſo in the common brandies. This is ſcarcely ever found in the firſt products of the diſtillation of wine, as the ſpirit begins to riſe at a much lower temperature than afterwards, but as the proceſs advances and the wine requires a greater heat for boiling, part of it undergoes that alteration which gives the empyreumatic flavour. It is alſo more prevalent where the alembic is too high and deep, ſo that part of the ſpirit is conſtantly falling back into the ſtill, and the proceſs is thus protracted to a great length of time. It may alſo at any time be given by encreaſing the heat and boiling the wine with too much vehemence. Chaptal, with ſome probability, attributes the ſource of this flavour to ſome decompoſition of the *malic* acid contained more or leſs in almoſt all wines, and which partly riſes with the diſtilled ſpirit. This acid is detected by forming inſoluble ſalts with lead, ſilver, mercury and lime, by not being cryſtallizable, and by other teſts deſcribed under that article, and it is found moſt abundantly in thin, ill-fermented wines, and in cyder, perry, and liquors made from harſh fruits. On the other hand the full-bodied rich wines are the moſt free from this acid. The more abundant the malic acid, the more will the ſpirit be acrid and empyreumatic, and that which is obtained towards the laſt contains enough of the acid to be very ſenſible to chemical teſts. The addition of chalk, alkali, or lime-water to the wine keeps down the acid very effectually, and renders the ſpirit much purer, but from ſome cauſe not eaſy to underſtand it remarkably diminiſhes the total quantity of product. From the caprice of faſhion however this empyreumatic flavour, though diſliked by the moſt delicate judges in the wine-countries, has become an excellence in ſome exported brandies, [c] and therefore muſt accordingly be given by the manufacturer.

[b] An. Chim. tom 37.

[c] Chaptal.

Another ſubſtance which gives a very ſtrong and generally a very unpleaſant flavour to brandy, appears to be an eſſential oil of a peculiar nature, and found moſt abundantly in the richeſt and fulleſt-bodied wines. It is certainly altered in the proceſs of diſtillation, and rendered nauſeous from being originally grateful and aromatic. When ſpirit charged with this oil is rubbed in the hands, as it evaporates it leaves its peculiar ſmell, which reſembles the breath of habitual drunkards. The very rich wines, particularly ſome of the Spaniſh, occaſionally are ſo full of this oil as to depoſit it in quantity on the capital of the alembic, where, when cold, it concretes into a ſtrong, nauſeous ſubſtance, of the conſiſtence of pomatum.[d] Spirits diſtilled with oils previouſly added to them in the alembic, ſuch as the malt-ſpirit brandies or imitations of brandy, are very liable to acquire a nauſeous flavour. Brandy diſtilled from theſe oily wines is in fact a ſaturated ſolution of eſſential oil in alcohol, and like any artificial ſolution of the kind it becomes milky on the addition of water, which, by uniting with the ſpirit ſeparates moſt of the oil in minute globules. Hence the addition of water to theſe oily brandies, with a cautious rediſtillation much improves the quality of the ſpirit.

Wine contains a peculiar *aroma* or perfume, but whether this can at all be conſidered as a peculiar principle diſtinct from the eſſential oil, is a matter of doubt. Yet from the delicate and periſhable nature of this aroma, and the permanence of the oil, perhaps ſome ground of diſtinction is obtained. Some of this delicate aroma appears to paſs into the firſt diſtilled ſpirit which it yields, though ſomewhat altered; but a ſecond rectification deſtroys it altogether.

The manufacture of brandy in other countries very much reſembles that of France, being equally ſimple, and the apparatus eſſentially the ſame. In Spain the principal brandy diſtilleries are in Catalonia. The wine yields on an average about a fifth of ſpirit of olive-oil proof (or that in which this oil ſinks) and about as much of an inferior ſpirit for rediſtillation. When the wines are old, heavy and oily, and a fine clear ſpirit is wanted at once, water is added to it in the alembic before diſtillation to ſeparate and keep down the oil. In Portugal the oil-proof is alſo eſtabliſhed, and the wines are moſtly full-bodied and oily.

An inferior kind of brandy is made from the *marc* of grapes, or the reſidue of the fruit after the juice has been made to flow out by the action of the preſs. This ſtill retains enough of the grape juice to be readily brought into fermentation, and conſequently to be able to yield a ſpirit by diſtillation. In Swiſſerland it is thus managed. Wine caſks are filled with the freſh marc quite full, and preſſed down by trampling to make it lie cloſe, which prevents it from moulding. The caſks are then headed, and the bung-holes and joinings cloſed up with clay. In two or three days the fermentation begins, the marc heats, and when the firſt working has ſubſided and it has acquired an agreeable vinous ſmell (which happens in from two to five weeks according to the ſeaſon) it is fit for diſtillation. In diſtilling it, the alembic may be filled quite to the top with the marc, for as it lies looſe and takes up much room, there is no danger of boiling over, water is then added, juſt ſufficient to wet it thoroughly, and a very moderate fire kept up during the whole proceſs. This precaution is particularly requiſite here to prevent the loweſt part of the contents of the alembic from burning and giving a very unpleaſant taſte to the ſpirit. Thirty-two cubic feet of marc are eſtimated to give about ten gallons of ſpirit, which however is rectified before it becomes very palatable. If the marc is not wanted immediately, it will keep without ſpoiling in well ſtopped caſks for two, three, or even four months.

Beaumé in his experiments on diſtillation ſuggeſts two good improvements in the above proceſs, whereby a good ſpirit may be obtained from the marc by the firſt diſtillation. One is by immerſing the alembic in a water bath, which effectually regulates the heat and prevents the poſſibility of any of the marc being ſcorched and hurting the flavour of the ſpirit. Another, and more convenient in the large way, is to prevent any of the marc from actually touching the bottom of the alembic, by interpoſing a kind of wicker cradle on which it reſts, and whereby it is raiſed an inch or two from the fire. Water is added as before, and its vapour penetrating the marc extracts and carries over all the ſpirit by a gentle boiling.

The improved alembic and refrigeratory are deſcribed in the Appendix (article *Apparatus*.) See alſo ALCOHOL, WINE, and DISTILLED Spirits.

BRASS or *Latten*. *Laiton*, Fr. *Meſſing*, G. This very important alloy is a mixture of copper and zinc in various proportions, ſo intimately united as to form a homogeneous malleable yellow metal, applicable to a vaſt variety

[d] Encycl Meth.

of purpoſes and capable of being wrought with the greateſt facility.

It is not eaſy to obtain a perfect union of zinc and copper by mere fuſion in open veſſels, for at a heat leſs than is required to melt the copper, the zinc readily takes fire and much of it burns off before it has time to mix with the other metal, ſo that the proportion of zinc is conſtantly leſſening by volatilization. Even after both metals are fuſed, the zinc continues to burn off in uncovered veſſels, and at laſt ſcarcely any thing but copper would be left. In order therefore to combine copper moſt intimately with zinc, and yet to preſerve its malleability, the ingenious proceſs of *cementation* has been reſorted to in the manufacture of braſs, which is performed by heating in a covered pot alternate layers of copper in ſmall pieces, with zinc ore and charcoal, and continuing the fire till the copper is thoroughly impregnated with the zinc.

Zinc being a volatile metal can only be procured from its ores by ſublimation; the proceſs for obtaining it (which will be deſcribed more at length under that article) being to heat ſtrongly a mixture of its ore with charcoal in a veſſel cloſed on all ſides, except where it admits a tube, the lower end of which dips in water: as ſoon as the charcoal reduces the oxyd, the metal riſes in vapour through the tube and condenſes in the water below. A ſimilar reduction takes place in braſs-making, only the vapour of the zinc inſtead of being conveyed out of the crucible in which it is formed, unites with the copper encloſed in the ſame veſſel, and the whole melts down into braſs. A leſs heat is required in braſs-making than that which fuſes copper, the zinc being able to penetrate the copper when thoroughly red hot, and melting it down as ſoon as it becomes braſs.

Braſs is manufactured in many countries, but no where more extenſively and better than in England, in which both the materials are in great abundance. The ores of zinc are ſeveral ſpecies of *calamine* and of *blende*, called by the miners *Black-Jack*, which are found abundantly in Devonſhire, Derbyſhire, and North-Wales, generally accompanying lead ores. Theſe are chiefly oxyds or carbonated oxyds of zinc, and require a previous calcination before they are fit for braſs-making.

At Holywell, in Flintſhire, the calamine which is received raw from the mines in the neighbourhood, is firſt pounded in a ſtamping mill, and then waſhed and ſifted in order to ſeparate the lead, with which it is largely admixed. It is then calcined on a broad ſhallow brick hearth, over an oven heated to redneſs, and frequently ſtirred for ſome hours. In ſome places a conical pile is compoſed of horizontal layers of calamine alternating with layers of charcoal, the whole reſting on a layer of wood in large pieces, with ſufficient intervals for the draught of air. It is then kindled, and the ſtack continues to burn till the calamine is thoroughly calcined. The calamine thus prepared is then ground in a mill, and at the ſame time mixed with about a third or a fourth part of charcoal, and is then ready for the braſs furnace. In ſome places pit-coal is ground with the calamine inſtead of charcoal, but this is found to injure the malleability of the braſs obtained.

The braſs-furnace[a] has the form of the fruſtum of a hollow cone, or a cone with the apex cut off horizontally. At the bottom of the furnace is a circular grate or perforated iron plate, coated with clay and horſe-dung, to defend it from the action of the fire. The crucibles ſtand upon the circular plate, forming a circular row with one in the middle. The fuel, which in England is coal, is thrown round the crucibles, being let down through the upper opening or ſmaller end of the cone: over this opening is a perforated cover made of fire-bricks and clay, and kept together with bars of iron ſo as to fit cloſely. This cover ſerves to regulate the heat in the following manner: the draught of air is formed through an under-ground vault to the aſh-hole, thence through the grate and round the crucibles, and through the ſmaller upper opening into an area where the workmen ſtand, which is covered by a large dome and a chimney to convey the ſmoke into the outer air. When the draught is the ſtrongeſt, and the heat is required of the greateſt intenſity, the cover is entirely removed and the flame then draws through the upper opening of the furnace to a conſiderable height into the outer brick dome; when the heat is to be leſſened the cover is put on, which intercepts more or leſs of the draught from the furnace, as more or fewer of the holes of the cover are left unſtopped.

The crucibles are charged with the mixed calamine and charcoal, together with copper clippings and refuſe bits of various kinds, and ſometimes braſs clippings alſo, moſt of which are previouſly melted and run into a ſmall funk ciſtern of water through a kind of cullender,

[a] Keir in a note to the article *Braſs* in Macquer's Chem. Dict.

which divides the metal into globules, like ſhot. Powdered charcoal is put over all, and the crucibles are then covered and luted up with a mixture of clay or loam and horſe-dung.

The time required for heating the crucibles and compleating the proceſs varies conſiderably in different works, being determined by cuſtom, by the quantity of materials, the ſize of the crucibles, and eſpecially the nature of the calamine. In the great way from ten to twenty-four hours are required. At Holywell, in Flintſhire, about twenty-four hours are taken.

During the proceſs, and eſpecially towards the latter end, part of the reduced zinc which eſcapes abſorption by the copper, finds its way in vapour through the luting of the crucible-lids, and burns around them with the beautiful blue flame and denſe white ſmoke peculiar to this metal.

The heat required for braſs-making is ſomewhat leſs than what would be neceſſary to melt large maſſes of copper, braſs being the more fuſible of the two, and, as it ſhould ſeem, the vapour of zinc being able to penetrate copper as ſoon as it is ſoftened by a full red heat. When the braſs is judged to be compleat, and the ſaturation of the copper with zinc to be as high as poſſible, the heat is increaſed to melt the whole down into one clean maſs at the bottom, the crucibles are taken out and the metal poured into moulds. At Holywell, out of the ſix crucibles uſed to one furnace, the quantity of braſs obtained is about as much as would fill one of them. This makes in ſubſequent manufacture a ſingle large plate, which is manufactured in the ſame way as copper plate. Or, more accurately, from forty pounds of copper and ſixty pounds of calamine, about ſixty pounds of braſs are obtained, beſides the loſs of a good deal of zinc by the unavoidable eſcape of much of it in form of vapour through the pores of the lute or the crucible-covers.

The above is the uſual proceſs of braſs-making in this country, and is eſſentially the ſame wherever this alloy is manufactured, but with ſome variation as to the choice of ingredients, their proportions, the time of fuſion, the ſhape of the furnace and other ſmaller circumſtances.

At Goſlar, in Saxony, where braſs is largely made, the zinc is furniſhed not by a native calamine but the *cadmia* or ſublimed oxyd of zinc, which is collected for this purpoſe in a particular part of the chimnies of the reverberatory furnaces in which the Saxon lead ores and blendes are roaſted.

A great variety obtains in the reſpective proportions of the ingredients. According to Swedenborg [b] they are, in Goſlar, 30 parts of copper, 40 to 45 of cadmia, and twice the volume of charcoal; at Paris, and in many of the French manufactories, they are, 35 of copper, 35 of old braſs, 40 of calamine, and 20 to 25 of charcoal; in Sweden, 30 of copper, 20 to 30 of old braſs, and 46 of calamine, with charcoal ſufficient; or, 40 of copper, 30 of old braſs, and 60 of calamine; and in England, generally about 40 of copper and 60 of calamine. The product of braſs varies alſo, but it ſeems to be in few places ſo great as in ſome of the Engliſh works, where, as already mentioned, 40 pounds of copper become in the proceſs 60 pounds of braſs. This ſuperior quantity is aſcribed partly to the goodneſs of the calamine and partly to the ſmallneſs to which the copper is previouſly reduced by being poured melted into cold water, and thus affording a great ſurface of metal to the action of the zinc vapour.

At Stolberg, [c] near Aix-la-Chapelle, where braſs is very largely manufactured, the furnaces are cylindrical, and each contains eight crucibles arranged in two tiers of four each. Theſe crucibles are fifteen inches high, twelve inches deep, and eight or nine inches wide. The proportions of ingredients are 40 lb. of copper, 65 lb. of calamine, and double its volume of charcoal. After the fire has been kept up for twelve hours, the crucibles are uncovered, and a workman takes off with an iron trowel all the ſcum and charcoal which ſwim upon the liquid metal, and which is called *arkeſt*. When examined with a glaſs, this is found to conſiſt of calamine and copper particles, cohering together but not compleatly united. The braſs reſulting from this firſt proceſs is coarſe, brittle, and unequal in texture, and requires a ſecond fuſion before it is fit for uſe. For this purpoſe the ſame crucibles are again employed and are filled, firſt with three handfuls of the mixture of calamine and charcoal, over which are put two or three pounds of the impure braſs broken in pieces, then more calamine and charcoal, with a lump of the *arkeſt*, and over all, calamine and charcoal powder. The crucible is then ſtrongly heated for two hours, after which the braſs is fit to be caſt into plates, which is done here in the following manner. A mould is formed of two blocks of granite, five feet long, three and

[b] Macquer's Dictionary.

[c] Repertory, vol. xiv.

a half broad, and eight inches thick. They are placed one above the other, the upper one being only moveable, and furniſhed with a tackle and pullies for that purpoſe, and before caſting, the ſurface is ſmeared with cow-dung. To give the plate the requiſite thickneſs, hoops of iron of different dimenſions are adapted to the under ſtone, ſo as to confine a determinate quantity of melted metal. The ſtones are then gently inclined and the melted braſs let in between them. Theſe plates are afterwards laminated: ſome of them are cut into ſlips by ſtrong ſhears, for the further purpoſe of being drawn into wire, and otherwiſe manufactured in various ways.

A ſingle proceſs, where the fire is kept up long enough and the materials are good, is certainly ſufficient to make good malleable braſs, but it is probable that the excellence and beauty of the article are improved by making it undergo a ſecond cementation with freſh calamine and charcoal.

In the laboratory braſs may be made very well in the ſmall way in a much ſhorter time.[d] Put into a crucible a mixture of calamine and charcoal, bury it in the requiſite proportion of copper ſhot, cover the whole with charcoal powder, lute on a cover to the crucible, and heat ſlowly in a wind-furnace for half an hour, till the zinc begins to burn off in a blue flame round the top of the crucible, then raiſe the fire and heat briſkly for half an hour longer.

This proceſs of cementation is alſo neatly ſhewn by the following management, as given by Cramer.[e] Put the mixture of calamine and charcoal into a crucible, cover it with a thin layer of clay, over which when dry lay a thin plate of copper, cover the whole with fine charcoal powder, and lute on a cover to the crucible. Apply heat gradually, and the vapour of the reduced zinc will riſe through the floor of clay, penetrate the red-hot copper plate above it, and gradually convert it into braſs, which at the end of the operation will be found lying melted on the ſtratum of clay. The increaſe of weight gained by the copper in this operation will afford a good practical teſt of the goodneſs of the calamine, and its fitneſs for braſs-making in the great way.

The moſt important properties of braſs compared with copper are the following: the colour of braſs is much brighter, and more approaching to that of gold; it is more fuſible than copper; leſs ſubject to ruſt and to be acted on by the vaſt variety of ſubſtances which corrode copper with ſo much eaſe; and it is equally malleable when cold, and more extenſible than either copper or iron, and hence is well fitted for fine wire. Braſs however is only malleable when cold. Hammering is found to give a magnetic property to braſs, perhaps however only ariſing from the minute particles of iron beaten off the hammer during the proceſs and forced into the ſurface of the braſs, but this circumſtance makes it neceſſary to employ unhammered braſs for compaſs-boxes and ſimilar apparatus.

The expanſion of braſs has been very accurately determined, as this metal is moſt commonly uſed for mathematical and aſtronomical inſtruments, where the utmoſt preciſion is required. Mr. Smeaton found that 12 inches in length of caſt braſs, at 32°, expanded by 180 degrees of heat (or the interval from freezing to boiling water) 225 ten thouſandth parts of an inch. Braſs wire under the ſame circumſtances expanded 232 parts; an alloy of 16 of braſs with 1 of tin expanded 229 parts. The expanſion of hammered copper is only 204 ſuch parts, but that of zinc is 253, ſo that braſs holds a middle place in this reſpect between its two component metals.

Moſt of the zinc readily burns off from braſs when kept melted in a ſtrong heat with free acceſs of air. When the heat is equal to that of melted copper, the zinc takes fire and ſlowly burns away. At laſt little elſe but copper remains, but ſtill united with a ſmall portion of zinc, which no further continuance of the fire will entirely ſeparate.

Some kinds of very fine braſs are ſaid not to be made by cementation in the way already deſcribed, but by a more ſpeedy and direct union of copper and zinc, care being taken to prevent the acceſs of air to the materials while in fuſion. Very fine braſs may alſo be made by mixing together the oxyds of copper and zinc, and reducing them with a carbonaceous flux. This idea is ingenious, and from the intimate mixture of the two metals which it promiſes, it deſerves to be further purſued. Sage gives the following experiment to this purpoſe.[f] Mix together 50 grains of the oxyd of copper, remaining after the diſtillation of verdigris (which is very pure) with 100 grains of lapis calminaris, 400 grains of black flux, and 30 grains of charcoal powder; melt the mixture in a crucible till the blue flame is ſeen no longer round the lid of the crucible, and when cold a fine button of braſs is found beneath the ſcoria, weighing a fifth more than the copper.

[d] Sage. [e] Ars docimaſt. [f] Journ. de Phyſ. vol. xxxviii.

alone, obtainable from its oxyd in the ſame way but without the calamine. This braſs has a very fine colour like gold.

On this experiment M. Sage obſerves that there appears to be a point of mutual ſaturation between the two metals, which is when the copper retains one-ſixth of zinc, and this portion it will retain however long it is heated, provided the ſurface of the melted metal be covered to protect the zinc from the action of the air; but if the braſs contains a greater proportion of zinc, preciſely this exceſs will eſcape, even in covered veſſels, and will burn when it comes out to the air. The ſame chemiſt alſo obſerves that the colour is the fineſt at the above proportion. Theſe experiments ſeem to require further confirmation, but at preſent we may reckon that to be the moſt perfect braſs which is compoſed of about 14.28 per cent. of zinc and 85.72 of copper, and which is not liable to any alteration in its conſtituent parts by ſucceſſive or long continued fuſions, provided the acceſs of air be prevented.

The analyſis of braſs has been attempted in various ways, and ſeveral proceſſes have been given of different merit.

Braſs may be to a certain degree analyſed by ſimply being kept in fuſion at a high heat with free acceſs of air. The zinc readily burns, and by far the greater part of it eſcapes, and when the blue flame of the metal ceaſes the analyſis is ſuppoſed to be compleat, the loſs of weight on the remaining metal indicating the quantity of zinc. But this is inaccurate from two cauſes; firſt, that a portion of zinc always remains in the copper however long the heat be continued, and ſecondly that part of the copper oxidates in the proceſs, and thereby gains an increaſe of weight. Both theſe circumſtances therefore contribute to indicate a ſmaller proportion of zinc than is really the caſe.

A ſimple ſolution of braſs in the ſulphuric acid and ſubſequent cryſtallization has alſo been recommended, on the idea that the cryſtals of ſulphat of zinc could readily be obtained ſeparate from thoſe of the ſulphat of copper. But though this ſeparation takes place to a conſiderable degree it is not compleat, for at the laſt the cryſtals of each ſalt are ſomewhat alloyed with the other, and the trouble of picking out the cryſtals when very ſmall is extreme.

M. Dizé[g] propoſes the following methods. 1. Diſſolve the braſs in nitric acid, which takes up the copper and zinc and leaves any tin with which it is often alloyed. Decompoſe the clear nitrated ſolution by potaſh, rediſſolve the precipitate in ſulphuric acid, and add a piece of clean bright iron to the ſolution, previouſly diluted with ſix times as much water. The copper is by this means precipitated in a metallic ſtate, and the ſolution now holds ſulphat of iron and ſulphat of zinc. Add gallic acid, which will ſlowly ſeparate the iron and leave the zinc. Laſtly, decompoſe the ſulphat of zinc by a carbonated alkali, and eſtimate the quantity of zinc contained in the carbonated oxyd of zinc thus obtained, by proportions which will be preſently mentioned. The above method is uſeful, but the ſeparation of the iron by the acid of galls is exceſſively tedious.

2. Diſſolve the braſs in nitric acid. Dilute with ſix parts of water, and immerſe in the ſolution a cylinder of bright clean lead. The copper ſpeedily ſeparates in the metallic form round the lead, which laſt takes its place in the ſolution. As this proceſs advances the liquor loſes its blue colour, and when all the copper is ſeparated it is ſlightly yellow. To be certain that no copper remains in the ſolution, add a freſh clean piece of lead and boil for ſome time. The liquor now contains nitrat of lead and nitrat of zinc. Sulphuric acid will now precipitate the lead in the form of an inſoluble ſulphat, and the nitrated zinc may then be decompoſed by a carbonated alkali.

On this precipitation however there are ſeveral things to be obſerved. Copper, as Vauquelin remarks,[h] when diſſolving in nitric acid abſorbs nearly $\frac{45}{100}$ of its weight of oxygen, but lead under the ſame circumſtance abſorbs only $\frac{16}{100}$. Hence 100 parts of copper diſſolved in nitric acid would require for their diſoxygenation (a proceſs which takes place whenever a metallic oxyd in ſolution is precipitated by the immerſion of another metal in its metallic ſtate) full 250 parts of lead, which laſt is of courſe oxydated in proportion as the copper is precipitated in the metallic form. But this large quantity of oxyd of lead cannot be held in ſolution by the nitric acid, except this is largely in exceſs, and this explains the reaſon of the appearance of a portion of oxyd of lead (as M. Dizé has obſerved) which forms at the latter end of the proceſs and mixes with the newly precipitated metallic copper, ſo as to require a ſubſequent operation to ſeparate them. Nor will an exceſs of nitric acid enſure the purity of the precipitated copper, for it happens here, as is now found to take place in very many of the reguline metallic precipitates, that the newly-ſeparated

[g] Jour. de Phyſ. tom. 48.

[h] An. Chim. tom. 28.

metal is not pure, but largely alloyed with the metal added as a precipitant. Therefore the loose flocculent metal which forms around the piece of lead is not pure copper, though it has a perfect cupreous appearance, but is copper largely alloyed with lead. Vauquelin found that if 50 grains of pure copper are diſſolved in an exceſs of nitric acid, and then entirely precipitated by metallic lead, of which about 220 grains are required, the cupreous precipitate now weighs 138 grains inſtead of the original 50, and therefore is not pure copper but an alloy of 50 parts of copper with 88 parts of lead. This method therefore of analyſing braſs cannot be depended on, unleſs the cupreous precipitate be afterwards ſeparately treated to ſeparate the lead, which would render the analyſis very complicated.

The following methods are given by Vauquelin.

3. Diſſolve a known weight of braſs in nitric acid; put it into a well cloſed bottle and add cauſtic potaſh to exceſs, ſo that there ſhall be a very ſenſible alkaline taſte in the liquor, ſhake the mixture well, and keep it ſome time in digeſtion. By this proceſs the oxyds of copper and zinc are firſt both precipitated by the alkali, and afterwards the zinc alone rediſſolved in the exceſs of potaſh, ſo that the clear ſolution is oxyd of zinc in potaſh, and the ſediment left undiſſolved is the oxyd of copper. This oxyd is brown and nearly of the colour of metallic copper, but when thoroughly waſhed and gently dried, it only contains 65 per cent. of the metal. If a previous aſſay has ſhewn that the ſpecimen of braſs contained only copper and zinc, when the weight of the former is known, that of the other may readily be inferred; or elſe, the alkaline ſolution of zinc may be ſuperſaturated with ſulphuric acid, ſo as firſt to precipitate and afterwards to rediſſolve the metal, when the ſulphuric ſolution may be decompoſed by a carbonated alkali. A very trifling quantity of copper paſſes into the alkaline ſolution of zinc, occaſioned by the action of a ſmall quantity of ammonia, generated by the nitrated metals when cauſtic alkali is added to them. If neceſſary this might be again ſeparated by a heat cautiouſly kept below boiling, which would expel the ammonia, the cauſe of this error, but if brought fully to boil ſome of the zinc would ſeparate from the alkali and cauſe a much greater error than before.

4. Diſſolve braſs in ſulphuric acid, dilute with twenty times as much water, and immerſe a ſtick of zinc exactly weighed. The copper ſoon compleatly precipitates in the metallic form, and requires only to be well waſhed and weighed. The ſolution now contains only the zinc of the braſs, together with the zinc loſt from the piece immerſed to precipitate the copper. By weighing the remainder of the ſtick of zinc, and precipitating the whole by carbonated potaſh or ſoda, an eaſy calculation will determine how much of the oxyd of zinc is derived from the zinc contained at firſt in the braſs. Or, more ſimply, this may be inferred from the copper obtained, and the quantity of braſs originally employed.

It remains on the ſubject of analyſis to give the conſtituent parts of carbonat of zinc. M. Dizé diſſolved 100 parts of zinc in nitric acid, precipitated it by carbonated ſoda, and this product well waſhed and *dried* now weighed 180 parts. Hence 100 parts of carbonat of zinc thus prepared would indicate 55.5 of metallic zinc.

On the other hand Vauquelin found that carbonat of zinc obtained from the ſulphat by carbonated potaſh, well waſhed, and calcined in a crucible to expel all the carbonic acid, contained 69 per cent. of metallic zinc. Hence the carbonat obtained by Dizé muſt have been dried at a low temperature, probably that of boiling water, and from either of the above data the proportion of zinc may be eſtimated; or elſe the carbonated oxyd may be mixed with about a fourth of charcoal and ſtrongly heated in an earthen retort with the beak dipping in water, by which the zinc will be reduced and will riſe into the neck of the retort, or partly fall into the water beyond.

Analyſis ſhews a vaſt variety in the proportions of the different ſpecies of braſs uſed in commerce. In general the extremes of the higheſt and loweſt proportions of zinc are from 12 to 25 per cent. of the braſs. Even with ſo much as 25 per cent. of zinc, braſs, if well manufactured, is perfectly malleable, though zinc itſelf ſcarcely yields to the hammer. M. Dizé analized a ſpecimen of remarkably fine braſs made at Geneva, for the purpoſe of eſcapement wheels and the nicer parts of watch-making, the perfect bars of which bear a very high price. This metal unites great beauty of colour to a very ſuperior degree of ductility. It was found to conſiſt of 75 of copper with 25 of zinc, and probably too the copper was Swediſh or ſome of the finer ſorts. The comon braſs of Paris ſeems to contain about 13 per cent of zinc, the Engliſh probably more.

The uſes of braſs are too numerous to be

mentioned. It is applicable to an infinite variety of purpoſes, is eaſily wrought by caſting and hammering, and by the lathe, its wire is eminently uſeful, and it takes a high and very beautiful poliſh. The appearance of braſs is given to other metals by waſhing them with a yellow lacquer or VARNISH, a ſubſtitution often very much to the detriment of the manufactured article.

Many other yellow alloys of copper are uſed, ſuch as bronze, bell-metal, &c. moſt of which are triple compounds, and will be noticed under the article COPPER.

BRAUNSPATH.[a] *Pearl-ſpar. Sidero-calcite* of Kirwan. *Spath bruniſſant* of Brochant. *Chaux carbonatée ferrifère* Hauy.

The colour of this mineral is milk-white, paſſing into greyiſh, yellowiſh or reddiſh-white; or roſe-red paſſing into fleſh, blood, or browniſh-red: when it has been expoſed for ſome time to the action of the weather it becomes firſt of a yellowiſh grey colour, and then verges into ochre or Iſabella-yellow, yellowiſh, reddiſh, liver and blackiſh-brown. It is ſometimes ſpotted, an accident that happens moſt frequently with the red-coloured varieties.

It occurs generally cryſtallized, and the forms of its cryſtals that are determinable are the ſame as certain varieties of calcareous ſpar. Its primitive figure is a rhomboid exactly correſponding with that of calcareous ſpar. The other figures are,

1. Equiaxe (of Hauy); a very obtuſe rhomboid.

2. Inverſe (of Hauy); an acute rhomboid, which is the primitive figure inverted.

3. Contraſtante (of Hauy); a ſtill more acute rhomboid than the preceding.

4. Baſée (of Hauy); the primitive rhomboid, the two ſummits of which are intercepted by two triangular facets.

5. Dihexaèdre (of Hauy); an oblique ſix-ſided pyramid, the alternate angles of which are equal.

The undeterminable forms of this mineral are,

6. Lenticular (lenticulaire of Hauy); which differs from the équiaxe in having the faces and angles rounded.

7. Curvilinear rhomboid (contournée of Hauy); a ſmall rhomboid, all the faces of which form a fold in the direction of their oblique diagonal.

It alſo occurs in minute interlaced rhomboidal ſcales, ſome of which have a conſiderable reſemblance to blende; or in globular maſſes or cellular.

The ſurface of the cryſtals is generally druſy, except of the rhombs, which are ſmooth. Its external luſtre is more or leſs ſhining, with a pearly luſtre, but when in a ſtate of commencing decompoſition it has uſually a variegated ſemi-metallic appearance. The fracture of braunſpath is ſtrait or curved-foliated, exhibiting a threefold obliquely interſecting cleavage, like calcareous ſpar. It flies when broken into rhomboidal fragments. It is tranſlucent on the edges, rarely entirely tranſlucent. Its hardneſs is a little ſuperior to that of calcareous-ſpar. Sp. gr. 2.83, according to Briſſon; the Iſabella yellow variety, according to Kirwan =2.39.

Before the blowpipe braunſpath crackles and falls to pieces, and becomes of a browniſh black colour (hence its name) but does not melt: with borax it runs into a frothy ſlag. By expoſure to a long continued high heat in a charcoal crucible, it becomes a dark brown friable maſs, ſtudded with minute metallic grains; in a clay crucible it produces a brown glaſs, tranſlucid on the edges and tranſparent in thin ſhivers.[b] It effervesces with acids, though feebly, and not except it is pulverized.

The maſſive variety, when calcined and mixed with ſand forms a ſtrong and valuable cement, which ſets quickly and is impenetrable by water.

The conſtituent parts of braunſpath, according to Bergman, are

50	carbonat of lime,
22	oxyd of iron,
28	oxyd of manganeſe.
100	

But a ſpecimen that was analyſed by Berthollet, at the deſire of Hauy, contained only about 4 per cent. iron and manganeſe, the reſt being carbonat of lime. On this account, and becauſe its cryſtallographical characters agree with thoſe of calcareous ſpar, M. Hauy combines the white or ſpathoſe iron ore with braunſpath under the name Chaux carbonatée ferrifère, and ranks it as a family of calcareous ſpar.

Many of the calcareous ſpars which are eſteemed pure, appear when analyſed by nitrous acid to contain iron; and perhaps a regular progreſſion may exiſt from calcareous ſpar with the ſmalleſt quantity of iron, to braunſpath, and finally to ſpathoſe iron ore, or carbonat of iron with the ſmalleſt quantity of calcareous ſpar. This however is as yet by no means aſcertained,

[a] Emmerling, Kirwan, Hauy, Brochant, Jameſon. [b] Klaproth. Analyt. Eſſ. i. p. 10.

and it is on many accounts more convenient to arrange the ſpathoſe iron among the ores of this metal, and to make diſtinct ſpecies of braunſpath and calcareous ſpar.

It occurs chiefly in veins accompanied by calcareous ſpar, ſpathoſe iron ore, galena, blende, pyrites, yellow copper, and various ores of ſilver. It is found in the mines of Norway, Germany, Sweden, France, Hungary, and England. At Ormes head, in Caernarvonſhire, it is found in veins with copper and manganeſe, and alſo very abundantly in maſs.

BRAZIL WOOD or *Fernambouc Wood. Sapan Wood.* The tree which bears this wood is the Cæſalpina Criſta, *Linn.* The wood is very hard, takes a high poliſh, and is ſo heavy as to ſink in water. When chewed it gives a ſweetiſh taſte. It much reſembles in appearance Red Saunders wood, but differs from it eſſentially in readily giving out its colour to water, which Saunders wood does not.

Brazil wood is valuable for the beautiful orange and red colours, in various ſhades, which it furniſhes to the dyer, but the colour is naturally very fugitive, though it may be to a certain degree fixed by various mordants.

When raſpings of brazil wood are boiled for ſome time in water they give a fine red decoction. The reſidue appears black, but alkalies will continue to extract a colour from it after the action of water is exhauſted. Spirit of wine and ammonia alſo extract a colour with great facility, which is ſomewhat deeper than the watery decoction.

When ſulphuric acid is added very gradually to a freſh watery decoction of Brazil wood,[a] a ſmall quantity of red precipitate falls down, and the clear liquor now becomes yellow. Nitric acid produces a ſimilar change, but the liquor is more of an orange. Moſt of the other acids alſo agree with the former in producing a red precipitate, and leaving the clear liquor of different ſhades of yellow or orange. The alkalies added to this liquor reſtore the original red colour, but with a caſt of crimſon or violet.

Brazil wood decoction, or infuſion in water, is readily turned of a violet or purple blue by alkalies, and this change is produced by ſo very minute a quantity as to furniſh a chemical teſt of the preſence of alkalies, of very great utility. According to Bergman,[b] in his valuable analyſes of mineral waters, 10 grains of cryſtallized carbonat of ſoda, which contains no more than about 2.15 grains of mere alkali, diſſolved in a Swediſh kanne (5.5 Engliſh pints) of water, give a ſenſible purple tinge to paper reddened by Brazil wood. There is however ſome ambiguity in this teſt, as the ſame change is produced by a ſolution of lime or magneſia in carbonic acid and water, a very frequent occurrence in moſt natural waters. Evaporating the water for ſome time will diſtinguiſh whether the change on Brazil wood is produced by an alkali or a carbonated earth; for, if by the former, the purple will be more intenſe in the concentrated water, as it now holds a greater proportion of alkali; but if by a carbonated earth, the effect will be loſt, as the boiling expels the looſe carbonic acid, and precipitates the carbonated earth which it held in ſolution.[c]

The effects of the ſolutions of tin and alum on Brazil wood are the moſt important to the dyer. Alum added to the watery decoction of the wood gives a copious fine red precipitate, inclining to crimſon and ſubſiding ſlowly. The ſupernatant liquor alſo retains the original red colour of the decoction, but if enough of alkali is added to decompoſe the alum, its earth falls down and carries with it nearly all the remaining colouring matter of the wood. In this way a fine crimſon LAKE, imitating the cochineal carmine, may be prepared, which therefore conſiſts of alumine, intimately combined with the colouring matter of the wood a little heightened.

Nitro-muriat of tin added to the decoction ſeparates the whole of the colouring matter, which falls down in great abundance in union with the oxyd of tin, and the liquor remains colourleſs. Even when the original colour of the wood has been previouſly altered by acids, the tin ſolution firſt reſtores the natural colour, and then precipitates the colouring matter as with the freſh decoction.

The ſolutions of iron blacken the decoction or infuſion of Brazil wood, ſhewing the preſence of the gallic acid.

Many of the other metallic ſolutions act ſimilarly to that of tin, in forming lakes, conſiſting of the colouring matter of the wood united with the metallic oxyd of the ſolution employed.

The colour of Brazil wood, though highly beautiful is readily fugitive, and has the additional diſadvantage of being darkened and rendered purple by ſoap, which therefore cannot be employed in waſhing cloth dyed with this colour. Acids render the colour permanent, but change it yellow. It is peculiarly diſtinguiſhed from the colouring matter of kermes and madder, by having the original crimſon-red reſtored by ſolutions of tin, after having been

[a] Berthollet. [b] Eſſays. [c] Kirwan on Min. Waters.

altered by acids. Accordingly the beſt practical dyers have employed acids and tin in their attempts to fix this beautiful colour. (See the article DYEING.)

BREAD. *Pain*, Fr. *Brot*, Germ.

Bread is a light porous ſpungy ſubſtance, prepared by fermentation and baking from the flour of certain farinaceous ſeeds, eſpecially wheat, and is the principal ſuſtenance of man in the temperate regions of the Northern hemiſphere.

It is not likely that the unprepared grains of wheat were ever the habitual food of man; for by maſtication the gluten that they contain coaleſces into a tough elaſtic maſs, equally unpalatable and indigeſtible. We read however of corn being fitted for uſe on ſudden emergencies merely by parching, and this was probably the ſimpleſt and earlieſt method of converting it into human food. The next advance was to pulverize the grains in a mortar or hand mill, to ſeparate the coarſe bran from the finer particles, and by the addition of water or milk to form theſe latter into a tough paſte, which being rolled into flat thin cakes was rendered eatable by toaſting on a hot ſtone or plate of metal. The Romans in the early period of their republic, and alſo the Carthaginians, appear, like the modern Italians, to have conſumed their corn pincipally in the ſtate of polenta or furmety, in which the wheat undergoes no further preparation than being boiled till the grains are ſwollen conſiderably and are become tender. By all theſe methods the moſt preſſing objection to the uſe of wheat, namely, its forming a tough glutinous maſs during maſtication, was completely got rid of, the action of fire alone, or of fire combined with water, producing the neceſſary change in the gluten with which this ſpecies of corn abounds. Still however it was deſtitute of that peculiar lightneſs and flavour which it acquires when converted into bread, properly ſpeaking, by a ſlight degree of fermentation.

The flour of wheat is compoſed of fecula or ſtarch, and a gluten exactly reſembling in its properties and compoſition the gluten of blood, together with a ſmall proportion of ſaccharine mucilage. When kept dry, and at a temperature not exceeding that of boiling water, it appears incapable of undergoing any ſpontaneous change, and continues in the ſtate of a fine impalpable powder, but if mingled gradually with a ſufficient quantity of water to form a thin tenacious paſte, and expoſed for a day or two to a warm air, the proceſs of ſpontaneous decompoſition begins to ſhew itſelf. The colour of the maſs becomes yellow, the flat ſub-nauſeous ſmell becomes acidulous and ſenſibly pungent, and the bulk is ſomewhat increaſed, owing to the diſengagement of ſmall bubbles of carbonic acid gas: theſe ſigns of fermentation preſently becomes more and more apparent, and the paſte paſſes rapidly into the putrefactive ſtate, exhibiting the uſual ſigns of this ſpecies of decompoſition, modified however by the acetous fermentation which takes place at the ſame time.

This change appears to be certainly begun and principally carried on by the gluten; although the *panary fermentation*, as it has been called, is ſuppoſed by many chemiſts to be produced by the contemporaneous action of three diſtinct fermentations, to which the three elements of wheaten flour are reſpectively ſubject. They imagine the vinous fermentation to take place in the ſaccharine mucilage, the acetous in the ſtarch, and the putrefactive in the gluten at the ſame time, and from the modification of each by the others, they conſider that peculiar action to originate which converts paſte into bread. Againſt this opinion however the following objections may be urged. In the firſt place, the quantity of ſaccharine mucilage is ſo extremely ſmall as to produce no ſenſible effect on the whole maſs, and what little there is probably paſſes immediately into the acetous fermentation. Secondly, the temperature that is required for bread-making is conſiderably lower than that at which ſtarch diſſolves in water, and where this is the caſe no alteration will take place, even in a long courſe of time: this is clearly ſhown by the uſual proceſs of ſtarch-making, in which the bruiſed wheat is fermented for ſeveral days in large vats, in order to deſtroy the gluten, after which the ſtarch is procured by ſimple depoſition from the waſhings of the reſidue. So eſſential is the preſence of gluten to the preparation of bread, that its perfection is almoſt exactly in proportion to the quantity which it contains of this ingredient. Hence wheat yields the beſt bread, becauſe it is compoſed of a larger proportion of gluten than any other grain, and hence rice, millet and oats are incapable of being converted into bread becauſe they contain little or none of it. In further confirmation of this it may be remarked that if the gluten of wheat (procured by ſimple waſhing as deſcribed under the article GLUTEN) be incorporated by careful kneading with rice-flour, a fermentable coheſive paſte is thus produced, from which perfect bread may be made in the uſual manner. It would be a curious enquiry, and one of no ſmall importance to the

inhabitants of the northern parts of Europe, to aſcertain how far the ſimple farinaceous ſeeds, and the oily farinaceous ones after expreſſion of their oil, are convertible into bread by mixture with the gluten of blood.

If wheaten dough is kept till fermentation is compleatly eſtabliſhed in it, as will be evident from its yellow colour and its aceſcent ſmell and taſte, it will be converted into *leaven*; and this leaven, if incorporated with freſh dough, will bring the whole into a fermenting ſtate, much more ſpeedily and uniformly than if the maſs was expoſed to ſpontaneous decompoſition.

The diſcovery of the advantages of mixing old dough with new appears to have been made very early, and the diſtinction between leavened and unleavened bread is noticed even in the moſt ancient hiſtorical records. Ancient Greece received from Egypt the important art of making bread, and tranſmitted it to Rome, whence it extended by degrees over the whole of Europe. But though leavened bread is perfect in every other reſpect, it always retains a ſlightly acidulous flavour from the leaven by which it is fermented, for it is impoſſible to carry the fermentation of the gluten to a ſufficient extent to change it into leaven, without at the ſame time exciting the acid fermentation in the ſugar of the flour. It was therefore a very important improvement in the art, and one which we believe is attributable to the Engliſh bakers, to ſubſtitute yeaſt or the froth of malt-liquor in a ſtate of fermentation, to leaven; for the former not only communicates no unpleaſant flavour to bread, but is alſo a more ſpeedy ferment, and by acting firſt on the gluten of the flour produces the deſired effect before any acid has time to be evolved from the other ingredients.

The proceſs of making common bread is extremely ſimple, though its perfect ſucceſs depends conſiderably on a kind of knack in manipulation, which cannot be deſcribed by words. It is of eſſential conſequence that the flour and yeaſt ſhould be mixed together with perfect accuracy, in order that the whole maſs may be equally fermented, and that this action may commence in every part at the ſame time. Now though in the making of a ſingle loaf this may eaſily be effected at one continued proceſs, yet where a conſiderable quantity of bread is to be made at once, this is impracticable.

The bakers of Paris have the reputation of being remarkably ſkilful in their buſineſs, we ſhall therefore have recourſe to the Encyclopedie[a] for an account of the moſt approved practice of this important art.

The ingredients of the beſt bread are wheaten flour, water, yeaſt, and ſalt. 150 lbs. of flour require about 85 pints of water, 3 pints of yeaſt, and a proportion of ſalt, which varies conſiderably according to the fancy of the baker and the degree of dryneſs which is to be given to the bread in the oven. The manufacture commences by diluting the yeaſt with about an equal quantity of warm water, and then ſtirring in one pound of flour for every pint of liquid; the whole being well incorporated it is put into a wooden bowl and ſet in a warm place for about ſeven hours, in order to ferment. At the end of this period the maſs (our Engliſh bakers call it the *ſponge*) is put into a large wooden trough and mixed with one-ſeventh of the whole quantity of flour, the whole of the ſalt, and with water in the proportion of one pint to two pounds of flour. The dough is now brought into a warm ſituation, and allowed to remain quiet for four hours that the fermentation may be eſtabliſhed throughout the whole: the ſalt ſomewhat retards the progreſs of this action, but at the ſame time has the advantage of rendering it more gentle and uniform. The next ſtep is to mingle two-ſevenths of the flour and three-fourths of its weight of water with the dough in the ſame manner as before, after which it is to be allowed two hours to ferment. Now commences the kneading and hard manual labour of the proceſs, during which the remaining four-ſevenths of the flour, and half as many pints of water as there are pounds of flour are to be thoroughly mingled with the fermented dough: at firſt the maſs is very adheſive and clings to the fingers, but it becomes leſs ſo the longer the kneading is continued; and when the fiſt on being withdrawn leaves its perfect impreſſion in the dough, none of it adhering to the fingers, this laborious part of the buſineſs is completed. The dough is now immediately divided by weight into loaf-pieces, each of which is once more ſeparately kneaded, and then made up into the proper form. The loaves as they are made are placed on a wooden table, and piled on each other two tiers high, and covered with a blanket to promote the laſt riſing or fermentation, which ſoon commences, and is judged to have proceeded ſufficiently far when a penetrating ſomewhat acidulous odour of carbonic acid is perceived. The oven is in the mean time heated, and when the tempera-

[a] Arts. & Metiers. art. Boulanger.

ture is ſuch that a little flour ſpread at its mouth is browned but not burnt, the loaves are depoſited within, the mouth is cloſed up with an iron door, and at the proper time (varying according to the ſize of the loaves) the bread is withdrawn, is replaced on the table and again covered with a blanket, in order to cool as ſlowly as poſſible; the aſhes and adhering flour are then removed with a bruſh and the bread is ready for ſale.

The changes produced upon dough by baking are very remarkable, nor can they in any degree be attributed to evaporation, ſince the loſs of weight never ought to exceed $\frac{1}{30}$, and is very often not greater than $\frac{1}{60}$. In the firſt place the progreſs of fermentation is entirely ſtopped: the bread may be kept for ſeveral days without experiencing any alteration, and the firſt ſign of ſpontaneous change is its becoming mouldy. Secondly, the tenacious ductility of the dough and its compact texture, are exchanged for a moderately firm and ſlightly elaſtic conſiſtence, and a very ſpungy texture, in conſequence of the alterations produced in the gluten by heat and moiſture. Thirdly, the fecula or ſtarch which was merely diffuſed through the dough without being in any degree affected by the *panary fermentation*, is combined during the baking with a portion of water into a ſtiff gelly, like common ſtarch when boiled with water, and thus renders the bread conſiderably more tranſparent than dough, as well as more digeſtible.

Rye and barley are the only ſubſtances beſides wheat that are capable of being made into bread, becauſe they alone contain gluten enough to admit of being formed into a moderately tenacious paſte with water. Even in theſe however, the proportion of gluten is too ſmall to afford light bread without the uſe of an acid ferment to diſengage the proper quantity of carbonic acid; ſo that they can never for the purpoſe of the baker be at all comparable to wheaten flour.

BRECCIA. *Breche*, Fr.

This term was firſt we believe employed by the Italian ſtatuaries to denote thoſe kinds of marble which are really or apparently compoſed of angular fragments of marble cemented together by a poſterior infiltration of calcareous ſpar or marble. Some of the French mineralogiſts have adopted the term and extended its meaning, ſo as to include any ſtony maſs compoſed of angular fragments conſolidated by a cement. Hence they ſubdivide the generic term *bréche* into calcareous, magneſian, ſiliceous, and argillaceous, and diſcriminate it from amygdaloid or poudingue (from the Engliſh pudding-ſtone) by reſtricting the meaning of this latter to ſtony maſſes formed of *rounded* pebbles imbedded in a cement. Neither this term nor any analogous to it is admitted into the nomenclature of the German mineralogiſts.

BRIMSTONE. See SULPHUR.

BRONZE. See COPPER *alloys of*.

BRUNSWICK-GREEN.[a] *Braunſchweigiſche grun*, Germ.

This is a pigment uſed by ſome of the German artiſts, and is prepared as follows. Take one part of muriated ammonia and make a ſaturated ſolution of it in cold water, put it into a tumbler, or any other convenient glaſs veſſel, and add to it three parts of copper clippings; cover the mouth of the veſſel with a piece of gauze to keep out the duſt, and place it in a warm ſituation, ſo that in a few days the moiſture will be evaporated. The muriat of ammonia preſently begins to be decompoſed by the copper, which in its turn is corroded and converted to a green oxyd. When the whole is evaporated to dryneſs, digeſt it in two or three ſucceſſive portions of ſpirit of wine, as long as any green oxyd is taken up, add the ſolutions together and drive off the liquor by a gentle heat; the reſidue is a pure dark-green ſub-muriat of copper, known in the ſhops by the name of refined Brunſwick-green.

BUTTER. See MILK.

BUTTERS MINERAL. A name given by the old chemiſts to ſome of the ſublimed metallic muriats, on account of their ſoft butyraceous texture when recently prepared. There are four metals which afford mineral butters, viz. Antimony, arſenic, biſmuth, and tin, and the peculiar properties of each of theſe ſalts are mentioned under the reſpective metals. The circumſtances in which they all agree are the following. They are formed by ſublimation; their conſiſtence is like that of common butter in warm weather, and a gentle heat reſolves them into a denſe oily-looking liquor; they are decompoſable by being dropped into pure water, a copious precipitation of white oxyd taking place. When the French nomenclature was newly introduced they were called oxymuriats: but it appears from later experiments that the exceſs of oxygen which they contain over the common muriats, is combined not with the acid but with the metal.

BUTTERS VEGETABLE. Such of the vegetable expreſſed oils as require a greater heat

[a] Gren. Syſt. Handb. iii. p. 334.

than that of the atmosphere to preserve them in a fluid state have obtained the name of *vegetable butters*. Of these the best known to Europeans is the *Palm* Oil, procured from the fruit of the Cocos butyracea. The common Cocoa-nut also, and the Chocolate-nut, may be made by pressure to yield a similar concrete oil. Mr. Park, in his travels in Africa, describes another tree, called by the natives Shea, from the fruit of which a very pure butter is also obtained. See Oils Vegetable *expressed*.

BUTTON. *Korn*, Germ. *Bouton*, Fr.

The rounded mass of metal which is collected at the bottom of a crucible after fusion, or which remains in the cupel after cupellation, is called by this name. If the button is solid, slightly convex and smooth on its upper surface, it is a sign of the process of reduction or cupellation having been well performed.

C

CACHOLONG. See Chalcedony.

CALAMINE. See Zinc.

CALCAREOUS EARTH. See Lime.

CALCAREOUS SPAR. See Limestone.

CALCINATION. *Calcination*, Fr. *Calciniren Verkalchen*, Germ.

CALX. *Chaux*, Fr. *Kalch*, Germ.

The term calcination is derived from the latin calx, which signifies quick-lime, and is applied by the old chemists to the conversion of a comparatively dense substance into a light and porous one, by the action of fire. The diminished specific gravity of bodies that have undergone calcination was supposed in all cases to prove the volatilization of one or more of their constituent parts, and as this was in many instances accompanied by combustion, the two terms came in some measure to be confounded. Hence in the writings of Glauber, Kunkel, and even Bergman, we find *ustus* used almost synonimously with *calcinatus*. There is however this distinction to be noticed between them, that *ustus* refers simply to the process, while *calcinatus* respects also the result of the process. Thus ustion may be performed repeatedly on the same substance, producing more or less change in it each time, but calcination when once brought about is perfect, and a pure calx is liable, by any subsequent exposure to heat, only to be vitrefied. For example: if a bone is placed in an open fire, the oil soon begins to exude and burns with a bright flame; when this ceases the residue is, properly speaking, *burnt* bone, and consists of earthy matter penetrated by charcoal; by a second exposure to fire the burnt bone loses its charcoal, and nothing remains but the white earth; it is now in the state of *calcined* bone or bone-ash, because it is incapable of any further decomposition by simple heat. A calx therefore is to a substance burnt in an open fire, what a *caput mortuum* is to a substance that has been distilled; they are each the ultimate results of the action of heat in open and in close vessels. Most metals when exposed to the joint action of heat and air are converted to a loose powdery substance which was denominated by the old chemists the calx of the metal, but which in the modern nomenclature is called an oxyd: and because the action of acids, especially the nitric, has a similar effect on some of the metals to that which is produced by fire, the term calcination when applied to these bodies indicated the conversion of them into calces either in the moist or dry way. But though the old term, as applied to metals, is superseded by oxidation, yet it may still very conveniently be retained to express the separation of the fixed from the volatile parts of bodies by means of a naked fire. In which sense we say calcined bones, calcined flints, calcined potash, calcined clay, &c.

CALCINED MERCURY. *Mercurius calcinatus*. A common pharmaceutical name for the simple red oxyd of mercury. See Mercury *oxyds of*.

CALCULUS *biliary*. See Biliary Calculus.

CALCULUS *urinary*. See Urine.

CALOMEL. See Mercury.

CALORIC or *Heat*. *Calorique*, Fr. *Warmestoff*, Germ.

The nature and properties of heat afford a most extensive and interesting subject for philosophical enquiry, which has been pursued with so much ardour and success that it would occupy a volume barely to enumerate all the researches to which it has given rise for the course of more than a century in many countries of Europe. We must therefore content ourselves with selecting the results of a few only, and particularly of those of later date, together with a general view of the present state of knowledge on this subject, which the experience of every year shews to be still imperfect, and still to promise a rich harvest of discovery for future enquirers.

The ſubſtitution of the term *caloric* to that of *heat*, has in a great meaſure ariſen out of the prevailing idea of the materiality of heat, whence it was thought neceſſary to guard againſt a confuſion of ideas that might ariſe from giving the ſame term to the ſenſation of warmth in the animal body, and to the cauſe of that ſenſation. But though the term caloric is well deviſed, it does not happen in fact that when its nature is underſtood, any material inconveience ariſes from this mixture of terms; and therefore in compliance with common language we ſhall uſe indiſcriminately the appellations of *heat* or *caloric* to imply that ſuppoſed material ſubſtance which poſſeſſes the power of exciting the feeling of heat in the animal body, together with a vaſt number of other properties, that render it the moſt important chemical agent in nature.

The general properties of caloric are the following: if material (and the phenomena which it exhibits are on the whole more readily underſtood by ſuppoſing it ſo) it is a ſubſtance of extreme ſubtlety and tenuity, entirely imponderable by human inſtruments, derived immediately from the ſun together with light, and, like light, obeying certain and ſimilar laws of reflection and refraction, and alſo elicited by combuſtion, by friction, and ſome other ſources: when uncombined, moving with immenſe velocity in every direction, and conſtantly tending to an equilibrium, penetrating all bodies in nature with more or leſs facility, and thereby enlarging their dimenſions without encreaſing their abſolute weight: when combined, probably entering into chemical union with other bodies, and thereby conſtituting the different ſtates of liquid, vapour, or gas: and laſtly, when applied ſuddenly to the animal body occaſioning the ſenſations of warmth, heat, or in greater intenſity, burning.

The ſimpleſt ſtate of caloric that we are acquainted with takes place when a heated body is placed in air, or any elaſtic medium much colder than itſelf. The great ſource of heat, the ſun, is probably in this ſituation, as likewiſe are all heated bodies, whether in combuſtion or not, ſimply expoſed to the atmoſphere. Thus ſituated, it is found that ſenſible heat is conſtantly radiating from them in every direction with immenſe velocity, and with an intenſity regulated by the nature of the heated ſurface, and its proportional exceſs of heat over the ſurrounding medium.

Again, when a body has been long enough expoſed to the radiations of heat to have itſelf received thereby an exceſs of caloric above that of the ambient air, it becomes a ſecondary radiating ſource, and immediately begins to ſend forth rays of caloric with apparently equal velocity with the primary ſource, and preciſely obeying ſimilar laws of tranſmiſſion. Thus a veſſel of water ſtanding near a hot fire firſt receives from it conſtant rays of heat, the water itſelf becomes hot, and it then begins to ſend off its acquired heat through the air to the ſurrounding objects. Hence the conſtant tendency to an equilibrium which radiant or ſenſible heat poſſeſſes, ſo that no heated body can remain an inſtant in contact with a colder one without loſing a portion of its caloric; and as the heat-evolving proceſſes are going on with unequal intenſity through every part of the material world, an eternal interchanging motion of caloric is every where perpetually kept up, which appears to be a grand agent in all the phenomena of nature.

But on the other hand there are two circumſtances which prevent or impede this conſtant tendency to equilibrium which caloric poſſeſſes, the one, the extreme retardation which heat experiences in its paſſage through ſolids and liquids, and the conſequent change in the mode of its propagation; and the other, the intimate and probably chemical union which takes place between part of the caloric and the body that receives it. Hence it is proper to have an appropriate term to diſtinguiſh the paſſage of caloric through ſolids and liquids, from that of *radiation*, which expreſſes its free and inſtantaneous paſſage through air or an attenuated medium. If a rod of iron is held with one extremity cloſe to a fire, the heat firſt radiates inſtantly to the neareſt end of the iron, and enters its ſubſtance, after which it paſſes (not immediately as before but ſlowly) through the whole length of the rod to the moſt diſtant extremity, ſo that ſeveral ſeconds elapſe before the hand holding the further end of the rod will be ſenſible of the paſſage of the heat. Now, as we ſhall preſently mention, it is probable that heat radiates with the ſame velocity as light, that is about 200,000 miles in a ſecond, whence may be conceived the immenſe retardation of its motion when it takes ſeveral ſeconds to paſs through an iron rod of a few inches only. Therefore it is probable that the caloric enters into a kind of combination with each particle of iron ſucceſſively in its paſſage through, and in this mode of propagation it is ſaid to be *conducted*. This faculty alſo varies very conſiderably, according to the nature of the ſubſtance heated; thus ſome metals conduct heat eaſier than others, theſe again

with more facility than glaſs, glaſs eaſier than wood, wood eaſier than charcoal, and the like. So that in treating of the ſubject of conducted caloric, the *conducting power* of the medium muſt be taken into conſideration. Late experiments have alſo ſhewn a peculiarity in the mode in which heat paſſes through liquids, which might juſtify in them the term *conveyed*[a] rather than *conducted*, but ſtill totally diſtinct from radiated.

Laſtly, there are ſeveral caſes in which caloric conveyed into a ſubſtance, either by being radiated or conducted, totally combines with it, loſing thereby the ſenſible properties which it before poſſeſſed when in a free ſtate, not raiſing the temperature of the body with which it is united, and contributing to form the ſtates of liquidity and vapour. The caloric which ice receives from the ſurrounding bodies when thawing, enters into this chemical union and converts it into the ſtate of water. The caloric is then termed *combined*, *fixed*, or *latent*, and comparatively in different bodies, *ſpecific-caloric*, and many moſt important enquiries are connected with this part of the ſubject.

Therefore in inveſtigating the laws and properties of heat it will be convenient firſt to fall in with the natural ſubdiviſions of the ſubject as relating to radiant, conducted, and combined caloric.

Of Radiant or Transmitted Caloric.

The firſt and moſt magnificent ſource of radiant heat is the ſun, whoſe rays are perpetually tranſmitting a vaſt ſupply of light and heat with immenſe velocity. The connection between light and heat was long a ſubject of much doubt and difficulty, but a late diſcovery of Dr. Herſchel has eſtabliſhed the very important fact of the ſeparate identity of theſe two bodies in the ſolar ray. The well-known circumſtance that the moon's rays, though condenſed by the moſt powerful lens or mirror, poſſeſs no aſcertainable heating power, is a proof of the exiſtence of light, ſeparate from heat, but ſtill capable of reflection and refraction by the ſame laws that regulate the motion of direct ſolar rays. Dr. Herſchel[b] in his optical experiments on coloured glaſſes was led to examine the difference between the coloured rays of the ſun, with regard to their heating power. He thereby diſcovered that the moſt refracted rays of light, the violet, poſſeſs the loweſt heating power; and the leaſt refracted, the red, the greateſt power, and the mean rays of the priſmatic ſpectrum ſhewed an intermediate power. Thus, in the red rays the thermometer (by the average of ſeveral experiments) roſe 6¼ degrees; in the green rays, 3¼ degrees; and in the violet, 2 degrees; or in round numbers, the effect of the red rays was to that of the green as 2.25 to 1, and to that of the violet as 3.5 to 1.

Purſuing theſe experiments, the ſame philoſopher found the range of diſperſion of the rays of heat by the priſm to differ moſt eſſentially from that of light; for on applying thermometers of great ſenſibility ſucceſſively in a line, beginning at the violet rays and proceeding along the priſmatic ſpectrum, he found not only that the heat encreaſed by advancing towards the red or leaſt refracted rays, but that the heat was greateſt at a ſmall diſtance beyond the extreme limits of the ſpectrum, that is, where no rays of light at all fell; and ſtill continuing to advance the thermometer in the ſame line, the heat then gradually diminiſhed till it became too ſmall to be noticed. This moſt curious and important diſcovery ſhews therefore both an entire ſeparation of heat from light in the ſolar ray, and a very different degree of refrangibility of one from the other, which together go near to eſtabliſh the ſeparate identity of caloric and light, and cauſe preciſely the ſame arguments uſed to demonſtrate the materiality of light to apply to the materiality of heat.

Theſe experiments of Dr. Herſchel have been fully confirmed by Sir H. Engleſield,[c] whoſe apparatus was ſomewhat different and more accurate. The particulars are as follows: the coloured rays of the ſpectrum were ſucceſſively and ſingly thrown on a lens (all the others being excluded by a ſcreen) and a thermometer with a blackened ball was placed in its focus, and allowed to remain there ſome time after it had ceaſed to riſe, that the full effect might be ſecured. Thus circumſtanced it roſe

In the blue ray from	55° to 56°
——— green ———	54 — 58
——— yellow———	56 — 62
——— red ———	56 — 72
Quite out of viſible light	61 — 79

Theſe experiments were repeated ſeveral times, and in all with very cloſely correſponding reſults, and the moſt ſtriking and novel phenomenon was manifeſt in all, namely, the *riſe* of the thermometer when paſſed beyond the extreme point of the luminous ſpectrum on the red ſide, and its *fall* when again carried back into the red light. It is to be obſerved that as theſe experiments were made in a London atmoſphere, in weather not uniformly bright, the numbers expreſſing the riſe of the thermometer

[a] Thompſon's Chemiſtry. [b] Phil. Tranſ. for 1802. [c] Jour. Royal Inſtit. No. 10.

are only to be conſidered comparatively. So palpable however is the difference of heat between even the red part of the ſpectrum and the contiguous dark ſide, that on ſhutting the eyes and moving the hand through the ſpectrum parallel to the priſmatic axis, a ſenſible encreaſe of temperature will without difficulty guide it to the point of greateſt heat beyond the red ſide of the ſpectrum.

The rays of heat are of a much more extenſive refrangibility than thoſe of light. This is immediately ſhewn by the circumſtance that in the ſolar priſmatic ſpectrum there are no rays that do not heat, whereas the rays of light fall far ſhort of the extreme point of the calorific rays, and even, as juſt mentioned, fall ſhort of the higheſt heating point. Dr. Herſchel eſtimates the baſe of the ſpectrum of heat to be to that of the ſpectrum of light as about 5½ to 3, but the degree of diſperſion of the heat-making rays differs ſo entirely from that of the rays of light, that neither do the mean nor the higheſt points of refrangibility agree, nor is there any obvious relation between the area of heat and that of illumination.

Radiant caloric appears to poſſeſs the ſame properties, and to be propagated according to the ſame laws whether tranſmitted from the ſun or from any other heated body, and whether or not it be accompanied by light. Thus the heat radiating from boiling water is reflected, refracted, and otherwiſe propelled preciſely in the ſame manner as ſolar heat. The following important properties the rays of heat poſſeſs in common with thoſe of light.[d]

They are ſubject to the laws of reflection.

They are ſubject to the laws of refraction.

They are of different refrangibility.

They are liable to be ſtopped in certain proportions when tranſmitted through diaphanous bodies.

They are liable to be ſcattered on rough ſurfaces.

Some of theſe properties require further illuſtration.

The concentration of heat produced by the reflection of the ſun's rays from a concave mirror is too well known to need further deſcription. It proves ſatisfactorily that heat when in conjunction with light, is, like light, capable of being reflected. The rays proceeding from a candle, ignited iron, and any other ſubſtance in luminous combuſtion are alſo well known to be capable of being reflected and concentrated into a focus by a mirror. But it is only comparatively of modern date that the *inviſible* rays of heat have been found to obey the ſame law of reflection, from whatever heated body the radiations proceed. The reflection of inviſible ſolar heat was aſcertained by Dr. Herſchel, by preſenting to a plain mirror the part of the ſolar priſmatic ſpectrum where the heat was the greateſt (that is beyond the extremity of the luminous ſpectrum on the red ſide) and with proper precautions cauſing the reflected rays of heat to fall on a thermometer. By this, in ten minutes, four degrees encreaſe of heat was indicated, whilſt another very delicate thermometer by the ſide of the firſt, but juſt out of the line of reflection, remained all the time quite ſtationary. Hence the reflection of the inviſible ſolar rays is proved.

But it was from experiments with culinary or artificial fire, that this moſt curious property of the reflection of radiant heat was firſt aſcertained. The following intereſting experiments were made by M. Pictet, on a plan ſuggeſted by M. de Sauſſure, who appears to have derived the firſt knowledge of the fact from M. Lambert. M. Pictet[e] placed two concave tin mirrors oppoſite each other at a diſtance of 12 feet aſunder. In the focus of one of the mirrors the bulb of a ſenſible thermometer was placed, and in the focus of the other was put the heated body which was the ſubject of experiment. By this ingenious arrangement a large portion of the radiant caloric proceeding from the heated body, if it followed the known laws of catoptrics, would firſt be thrown upon the mirror in whoſe focus it was placed, thence would be reflected in parallel rays to the ſurface of the oppoſite mirror, and from this would be concentrated into its focus where the thermometer ball was placed. This arrangement was well calculated to render ſenſible the effect of a heated body of very ſmall dimenſions. On putting an iron bullet heated below redneſs into one focus, the thermometer in the other roſe 10.5 degrees (of Reaumur) in ſix minutes, beginning its riſe the inſtant the ball was in its place. A lighted taper uſed inſtead of the ball had nearly the ſame effect. But to take away all poſſibility of the interference of light, a glaſs matraſs full of boiling water was now ſubſtituted, and in two minutes the thermometer roſe 3⅛ degrees of the ſame ſcale. When the bulb of the thermometer was blackened, the effect was proportionally greater. The riſe begins the very inſtant that the heated body is put in its place. The diſtance of 69 feet pre-

[d] Herſchel. [e] Eſſai ſur le Feu.

duced no aſcertainable interval of time between the cauſe and effect, which is not ſurpriſing, ſince it is highly probable that the motion of calorific rays is full as rapid as thoſe of light.

Theſe moſt beautiful experiments, with many others on the propagation of heat, have been repeated with various modifications by Mr. Leſlie,[f] with an apparatus of equal ſimplicity and elegance, and with thermometers of a peculiar conſtruction and admirable ſenſibility.

The important diſcoveries contained in this intereſting reſearch make it neceſſary to extend the ſubject of the propagation of radiant heat to the conſideration of the power or aptitude of (comparatively) hot bodies to propel or diſcharge heat in a radiant form from their ſurfaces, and of (comparatively) cold bodies to receive and abſorb caloric radiating to their ſurfaces. In the former caſe caloric paſſes out of a combined to a radiated ſtate; in the latter, the contrary takes place. The beautiful experiments which we are about to relate ſhew a very uniform agreement between theſe two contrary powers, and prove that the power of abſorbing radiant heat poſſeſſed by different bodies or ſurfaces of bodies, is exactly equivalent to their power of tranſmitting heat in a radiant form.

The apparatus uſed by Mr. Leſlie was the following. A thermometer with a double bulb, conſtructed in ſuch a manner that a riſe or fall on the ſcale would take place only when the indicative bulb was expoſed to a higher or lower temperature than the other bulb, or than the ſurrounding air. This the inventor terms a DIFFERENTIAL THERMOMETER, and its conſtruction will be explained under that article. The peculiar advantage which it poſſeſſes, beſides its extreme ſenſibility, is, that in uſing it the common temperature of the ſurrounding air may in general be diſregarded, this being always the zero of the ſcale, whatever be the actual variation of heat in the ſurrounding atmoſphere: and hence a much greater ſimplicity is introduced in theſe delicate reſearches. For the reflection of heat, mirrors were employed, generally of block-tin, highly poliſhed, and hammered to fit a wooden gage, the ſegment of a parabolic curve, whereby much of the diſperſion produced by a ſimple concave form was avoided, ſo that when expoſed to the direct rays of the ſun they collected them into a pretty diſtinct focus of about half an inch in diameter. The ſubſtance employed to generate the radiant heat was a hollow cubic tin caniſter, whoſe ſtation was directly in front of the mirror of its focal point, and when uſed, was filled with boiling water, and fitted with a common thermometer paſſing through a hole in the cover and immerſed in the water. The cubical form of the caniſter allowed of four ſides of perfectly equal dimenſions, each of which, when turned to the mirror, afforded a heated ſurface for the tranſmiſſion of radiant caloric, and they were occaſionally coated with various ſubſtances to aſcertain the effect of colour, poliſh, and the like, in retarding or promoting the radiation of the heat within.

Some of the principal experiments we ſhall relate.

The bulb of the thermometer being in the focus of the mirror, if the caniſter is filled with boiling water and ſet oppoſite to the mirror, generally at the diſtance of three feet, the liquor of the thermometer begins to riſe immediately, and in a few minutes has attained its greateſt point of elevation, after which it ſlowly ſinks as the water cools, till at laſt it returns, in perhaps about two hours, to the ſtandard of the atmoſphere, at which point, whatever be the actual temperature, the differential thermometer remains at the zero of the ſcale. This experiment, like that of M. Pictet as above related, ſhews the ſimple reflection of caloric radiating from the ſurface of the heated caniſter. With a ſix-inch caniſter, three feet from the mirror, the total riſe of the differential thermometer was about equivalent to 14.5° degrees of Fahrenheit. Mr. Leſlie alſo found that in all caſes the full effect of the radiant heat on his thermometer was exactly proportioned to the heat of the caniſter above that of the room. Thus if the water in the caniſter is at 200° and the room at 60° (making a difference of 140), and the full riſe on the differential thermometer amounts to 84 degrees of any ſcale, a difference of 100 degrees will cauſe a riſe of 60° in the ſame thermometer, for 140 is to 84 as 100 to 60.

The effect of altering the ſurface of the heated body whence the radiations of heat originate, is ſhewn in a very ſtriking manner by the following experiments. Of the four equal ſides of the cubic tin caniſter, one was covered with lamp-black, a ſecond with writing paper, a third with glaſs cemented on by pitch, and the fourth left unaltered. The caniſter being filled with boiling water, and each ſide being turned ſucceſſively to the mirror, the effects were ſurprifingly different. The firſt or blackened ſide raiſed the thermometer 100° (of an arbitrary ſcale); the ſecond or papered ſide,

[f] Inquiry into the Nature of Heat.

about 98°; the third, or glazed, gave 90°; but the polished tin side gave only 12°. From this curious experiment it appears that a polished metallic surface has no more than about an eighth part of the power of propelling heat possessed by a soft unpolished surface.

To shew that this difference of the transmitting or propelling power was correlative with that of the receptive power, as abovementioned to be the case, the bulb of the thermometer was now coated with tinfoil pressed smoothly down, so as to imitate very exactly the polished surface of the canister. The blackened surface of the canister being now presented to the mirror (which produced an effect of 100 degrees on the plain bulb of the thermometer) now raised it only 20°; and when the plain surface of the canister was presented (which before had given 12°) it now gave only about 2.5°.

The inference from these experiments is, first, that the propelling and absorbing powers of surfaces relatively to radiant caloric are always in the same proportion, and that this power is many times less in bright metallic surfaces, than even in glass, and still more in soft unpolished surfaces such as black paint or paper.

The power of absorbing, and of propelling or transmitting heat, being coexistent and correlative in the same substance, they must both be in direct opposition to that of reflecting heat, the surfaces which the most oppose the reception and propulsion of heat being those which reflect it the most powerfully. The experiments just related shew that the polished metallic surface of the canister with difficulty transmits caloric, and that the metallic coating of the thermometer bulb prevents its absorption of heat; the following experiments shew how much superior power of *reflecting* heat is possessed by a metallic over a glazed or any other surface.

In the place of the tin reflector (of the apparatus before described) substitute a concave glass mirror, and put the naked thermometer-bulb in its focus as before; then fill the canister with boiling water and present the blackened side. The effect will now be very small, but determinate. Rub off the silvering from the back of the mirror, and the effect remains the same. Roughen the back by grinding with emery, the same effect is produced. Cover the anterior surface of the mirror with Indian ink, and all effect on the thermometer ceases. Cover the face of the mirror with tinfoil, and the rise of the thermometer will now be ten times as much as with the smooth surface of glass. The same difference between the reflecting power of glass and that of metal had been observed by M. Pictet, who ingeniously supposes that the radiant heat first penetrates the anterior or glass surface of the mirror, and proceeds (much obstructed) to the metallic coating on the back, from which it is reflected and passes back out of the anterior surface into the atmosphere. Hence the great loss of heat is accounted for by its double passage through the entire thickness of glass. But the circumstance that the reflecting power continues just the same with or without the silvering of the mirror at the back destroys this hypothesis, and hence the explanation will be, that glass being a better absorber of radiant caloric than polished metal, takes in the greater part, and reflects only a small portion from the surface, against which the radiant heat first strikes. Hence too by covering the glass with a soft coating of black ink, the absorbing power is still more encreased, and consequently the reflecting power proportionably diminished.

No delicacy of experiment is required to shew in a general way the vast superiority of metal over glass in reflecting heat. Thus if the commonest tin reflector, at all approaching to a concave or parabolic form, be held several feet from a large fire, and the finger put in the focus, a very considerable warmth will be perceived; whereas the best glass mirror of the same dimensions and at the same distance, will hardly collect in its focus heat enough to be felt.

The following scale of effect produced by the above apparatus of Mr. Leslie, will serve to give a clear idea of the subject. Oppose the bright side of the tin canister filled with hot water to a glass mirror, and coat the thermometer-bulb with tinfoil. Here the canister, the mirror, and the bulb are all in the most unfavourable circumstances for the transmission, reflection, and absorption of radiant caloric. The rise of the thermometer will be very small, call it equivalent to 1 degree. Then cover the face of the glass mirror with tin-foil, which will have the same effect as substituting a metallic mirror, and this reflexion will be so much encreased that the thermometer will rise to 10°. Then take off the tinfoil from the bulb, whereby its absorbing power will be encreased, and it will rise to 50°. Lastly, present the blackened side of the canister, which transmits caloric with the most ease, and the full effect will now be 400°, as every circumstance is now the most favourable to the transmission and reflection of heat.

For experiments where great nicety is not required, as polished metallic specula are

expenſive, and even hammered tin reflectors not very eaſily procurable, a reflector caſt of Paris plaſter and gilt on its anterior ſurface [r] will anſwer very well, and the reflection of heat from this cheap inſtrument will ſtill be much greater than from any glaſs mirror of equal dimenſions.

The above experiment of Mr. Leſlie ſhew therefore a correſpondence between the power of propelling and abſorbing heat: a continuation of the ſame reſearches throw further light on the curious queſtion how far the propulſion of heat is affected by the nature and condition of the propellent ſurface. A few only of many experiments can here be related. With the apparatus of the caniſter and mirror above deſcribed, the effect of the plain tin ſide in propelling caloric is equivalent to 12 degrees of the differential thermometer when that of the blackened ſide (aſſumed as a ſtandard) is 100°. The tin being rubbed with mercury ſo as to be of a dull white, gave 14°, but being ſoaked with mercury ſo as to form almoſt a reſplendent coating of this metal, gave 20°. Hence we may infer that the propellent power of mercury is about double that of tin.

The effect of the ſucceſſive degrees of oxydation of the ſame metal is ſtriking. A clean rough ſurface of lead produces 19° of the thermometer; the ſame, tarniſhed with a grey cruſt by expoſure to air, gives 45°; a coating of minium gives 80°; ſealing-wax and roſin each gives about 95°.

The degree of poliſh or evenneſs of ſurface alſo much influences its power of propelling caloric, which encreaſes in proportion as the ſurface is roughened. Thus the effect of ſmooth hammered tin being always 12°, when ſcraped to a bright but irregular ſurface it amounts to 16°; when ploughed by a ſmall-toothed plane-iron, with intervals of $\frac{1}{10}$ of an inch between the teeth, the effect riſes to 19°; when thoroughly filed over the whole ſurface it amounts to 26°. Thus if ſmooth tinfoil gives 12°, the ſame rubbed in one direction with ſand-paper gives 22°. But if the ſcratches are much multiplied, an approach to ſmooth poliſh is made, and the effect is again diminiſhed.

The *thickneſs* of the propellent ſurface, or more accurately the thickneſs of a ſtratum of matter applied to a heated ſurface and of a different nature from it, alſo in ſome caſes conſiderably modifies the propellent power.

A ſmall portion of liquefied jelly ſpread on a ſmooth ſurface of the tin caniſter, and dried to a very fine irideſcent pellicle, gave 38° (the effect of the unſmeared tin being always 12°); a pellicle of four times the thickneſs gave 54°; a thick layer of iſinglaſs gave about 80°. This encreaſe however has its limits, for after the thickneſs amounts to the thouſandth part of an inch, the propellent power is not encreaſed by any ſubſequent additions. This rule does not apply however to any metallic coating applied to glaſs or other metal. The effect in this inſtance is purely that of the metal at the ſurface, and is not at all modified by the thickneſs. Thus tinfoil applied to glaſs appears to have the ſame propellent power as a ſolid plate of tin whoſe ſurface has the ſame denſity, ſmoothneſs, and poliſh as the foil, and a ſingle thickneſs of gold leaf produces the ſame effect as any number of leaves.

The *colour* of the heated ſurface appears to modify in ſome degree its receptive and propulſive power with regard to caloric. Thus black ſeems to have theſe powers in the higheſt degree, the higheſt effect in the above experiments being produced by a coating of ſize and lamp-black, but as the nature of pigments varies extremely, ſome being ſimply vegetable matter, and many of them metallic oxyds, it is difficult to obtain any accurate reſults on this ſubject. Thus, white paper produces nearly the ſame effect as lamp-black, and ſtained paper nearly the ſame as white.

The modifications of the propulſive and abſorbent power according to the nature, texture, and ſtate of the ſurface of the propelling, or the abſorbing body, are beautifully illuſtrated by extending the ſame experiments to the *reflection* of caloric. Here, as already mentioned, the range of the above effects will be entirely reverſed, as the ſurfaces that propel and abſorb heat the moſt readily are thoſe which reflect it with the greateſt difficulty, and vice verſa.

The reflective power of different metals might be aſcertained by cauſing reflectors of equal dimenſions to be made of the reſpective metals, but as this method would be difficult and expenſive, Mr. Leſlie ingenioufly took advantage of the ſecondary reflection produced by placing a circular flat plate or diſk of the metal to be examined, parallel to the face of the tin reflector, and nearer than the proper focus. This by the laws of catoptrics (which apply equally to the propagation of heat) will produce a ſecondary reflection from the diſk, whoſe focus will be ſituated as much before it as the focal point of the reflector is behind it. Under theſe circumſtances the thermometer, whoſe bulb was placed

[r] Pictet.

exactly in the ſecondary focus, was raiſed in the following degree by diſks of different metals returning the reflected heat of the caniſter, viz. braſs 100°; ſilver 90°; tinfoil 85°; ſteel 70°; lead 60°; tinfoil made bright by the affuſion of mercury 50°. A diſk of glaſs produced only 10°, and coated with wax, only 5°.

Roughening the tin ſurface of the caniſter was found in the former experiments to *encreaſe* the propelling power: hence the ſame operation performed on a mirror lined with tinfoil *diminiſhed* the reflecting power to nearly one-tenth of its former intenſity.

A tin reflector coated with a pretty thick layer of tallow had its reflecting power reduced from 100° to 8°, but again encreaſed to about 40° when moſt of the tallow was melted off.

Tin reflectors were coated with iſinglaſs by pouring a little of the liquefied jelly into the hollow of the mirror, and turning it round conſtantly till the whole ſurface appeared to be uniformly coated with it, which dried into a ſmooth and nearly tranſparent membrane. The reflecting power was immediately reduced by the wet jelly from 100° (the power of the clean reflector) to 31°, but as the coat of jelly gradually dried, the power again encreaſed gradually to about 72°. This ſhews very ſtrikingly the effect of the thickneſs of the ſtratum, ſince in drying, it muſt gradually have ſhrunk, till at laſt it became only a fine film of membrane. An encreaſed quantity of jelly alſo diminiſhed the reflecting power, but the exact law of diminution is not eaſily aſcertainable.

As in the caſe of propelled caloric, a metallic coating, however thin, produced the ſame effect on the reflector as if it had been entirely made of the covering metal; ſo when the bulb of the thermometer was coated with a ſingle thickneſs of gold-leaf, its abſorbing power was ſo much leſſened as to produce no more than about a fifth of its natural effect.

It has been mentioned that when radiant heat, from whatever ſource derived, is obſtructed in its paſſage by any ſolid body, the portion which is not reflected from its ſurface enters its ſubſtance, combines with it, and then aſſumes a new form; ſo that the pulſatory energy which it received from the propellent ſurface is totally loſt by this combination. In other words, the caloric is not *propelled* through a ſolid body, but unites with it in a different mode, and raiſes its temperature, till the ſolid ſubſtance becomes a new and ſecondary or derivative ſource of calorific radiations, which are again propelled from its ſurface, not according to the original propellent force, but according to that which belongs to the nature and condition of the ſurface of the ſecondary heated body.

This is alſo illuſtrated by very curious experiments taken from the ſame author. Some of them are the following:

Place the frame of a ſcreen between the caniſter and the mirror (in the apparatus all along deſcribed), over which ſtretch any ſubſtance to be the ſubject of the experiment. The ſcreen ſhould be large enough totally to intercept all communication of heat between the caniſter and the mirror. When a thin ſheet of tinfoil is the ſcreen, the radiant heat from the caniſter is ſo compleatly intercepted that no ſenſible effect is produced on the thermometer bulb beyond it in the focus of the mirror.

Subſtitute a pane of glaſs to the tinfoil, and the effect produced on the thermometer will now be about 20°, the full effect without the encloſed ſcreen being 100°.

Glaſs is permeated by light, which ſuffers however a certain diminution or abſorption in its paſſage. But this diminution is proportionally the ſame whether the light is in a diffuſed or condenſed ſtate, and therefore is the ſame whether, in the above apparatus, the glaſs ſcreen be more or leſs near to the radiating ſource. Not ſo with heat, for the riſe of the thermometer is the greateſt when the glaſs ſcreen is cloſe to the caniſter (not actually touching it) and diminiſhes in proportion as the ſcreen is advanced towards the mirror. Hence it follows that the propagation of heat through glaſs is made in a different mode from that of light.

Cauſe two ſheets of tin to be painted black on one ſide only, and put them in cloſe contact with their bright ſides outermoſt. No ſenſible effect will now be produced in the bulb of the thermometer. Invert the tin plates ſo that the painted ſides are outermoſt, and an effect of 23° will follow. Remove one of the plates, and the thermometer will ſhew 4°.

This experiment well illuſtrates the nature of the propellent and abſorbing powers of ſurfaces already deſcribed, ſince the ſubſtance of the ſcreens is exactly the ſame, and only their relative poſition altered: and it is clear that the radiations only affect the ſurfaces of bodies, ſince when the ſcreens are in cloſe contact, the inner and touching ſurfaces of each produce no ſenſible alteration on the propulſive power, but communicate their heat by the conducting power. When one plate is removed, though the actual thickneſs of the ſcreen is diminiſhed one-half, one of the ſurfaces is now metallic,

and conſequently propels caloric with much leſs force than when both outer ſurfaces were painted.

Place each half-blackened tin ſcreen on ſeparate frames; join them together, and the effect on the thermometer will be 23°; put them two inches aſunder, and the effect will not be perceptible. The ſcreen the furtheſt from the caniſter in this caſe only receives a doubly derivative caloric (being propelled from the firſt ſcreen, which is itſelf a ſecondary ſource) which is ſo much enfeebled in its paſſage as to be imperceptible by the thermometer.

From a number of experiments it is obvious that heat radiates from the ſurface of the propellent body, like light, not only in perpendicular but in divergent lines. It becomes a queſtion whether the radiating or propulſive energy is at all modified by the direction which it takes from the propellent ſurface. Mr. Leſlie found that the effect of a heated cubic caniſter was the greateſt, when the radiating ſide was exactly parallel to the mirror, and decreaſed gradually when an oblique direction was given by turning it on its center, and thus preſerving the ſame diſtance. The law of this decreaſe appears to be proportional to the degree of obliquity, whence it may be laid down as a general rule that the action of a heated ſurface is proportional to the ſine of its inclination, and therefore is greateſt in a direction perpendicular to the ſurface.

The times taken up by the reſpective cooling of heated bodies expoſed to a cold atmoſphere or any other elaſtic medium, equally illuſtrate all the preceding obſervations concerning the effect of ſurfaces in promoting or retarding the radiation of heat. Thus when a hollow tin ball is filled with hot water and ſet to cool in a tranquil atmoſphere, if it takes 156 minutes to cool down to a given point when the ſurface is bright and clean, the ſame, painted with lamp-black, will cool to the given point in 81 minutes. [h] This indeed does not accord with the proportional propulſive energy of theſe two oppoſite ſurfaces in the experiments of the reflexion of radiant caloric already mentioned; for in theſe it was found that the force of radiating caloric from theſe two ſurfaces was as 96 to 12, or eight times as ſtrong in the blackened as in the bright metallic ſurface. Whereas the actual rate of cooling is only four to one, or four times as great in the painted as in the metallic ball. Some other cauſe than radiation muſt therefore act in this caſe, and muſt act nearly equally upon both ſurfaces, ſince it tends to diminiſh the relative proportions between the cooling power of theſe two ſubſtances. This will be mentioned in the next ſection, when treating of the conducting power. The actual law of cooling that regulates all bodies immerſed in a fluid medium, will be preſently noticed.

Radiation of caloric has been obſerved to take place only in elaſtic mediums, or perhaps in a vacuum, but certainly not in water. To prove this, if the apparatus of the heated caniſter and mirror be immerſed in water, no riſe whatever takes place in the differential thermometer when placed in the focal point. [i] Likewiſe, a clean bright tin ball filled with hot water and immerſed in cold water, cools down to a given point as ſoon when the ſurface is bright as when painted.

Several important practical inferences may be drawn from the properties of radiated caloric, and the power of different ſurfaces to propel, abſorb, and reflect radiated heat. Many of theſe are in direct oppoſition to commonly received opinions. Thus in caſes where it is required to preſerve the heat of any ſubſtance confined in a metallic veſſel, the external ſurface ſhould be kept clean, bright, ſmooth and poliſhed; [k] on the other hand, if the object be to cool them quickly, the ſurface ſhould be painted or tarniſhed, or covered with a thin layer of ſome ſoft unmetallic coating. For example, metallic pipes intended to convey ſteam uncondenſed to a diſtance ſhould be kept bright, or may advantageouſly be gilt, as the thinneſt poſſible coat of gilding will anſwer the purpoſe of diminiſhing as much as poſſible the quantity of radiated caloric. On the contrary, metallic pipes or flues conveyed into a room with the view of warming it, ſhould be rough, unpoliſhed, tarniſhed, or better, painted.

Some limit however is put to the calculation of the gain or loſs of caloric by radiation, by the circumſtance that conducted caloric (which will preſently be deſcribed) in very many caſes has preciſely an oppoſite range of action. Thus metallic bodies conduct heat with much more facility than glaſs or wood of equal thickneſs; and hence when a perſon touches a metallic veſſel containing a hot liquid, the heat is ſo rapidly *conducted* to the finger as immediately to become intolerable; and yet, as has been fully ſhewn, the ſame veſſel keeps its contained liquid much hotter in the air in a given time than a glaſs or wooden veſſel of the ſame dimenſions, which the hand could touch without uneaſineſs.

[h] Leſlie. [i] Leſlie. [k] Rumford.

So that the heat of the outside of any vessel to the touch is no other criterion of the ease with which heat radiates from it, than to make it probable that the surfaces which feel the hottest are from their nature those which retain heat the longest in the air, or any elastic medium.

The thickness of any vessel, more especially if as much as possible of it is made of light spongy materials, directly diminishes the conducting power, though it often encreases the radiating. Thus a metallic vessel will cool *faster* than before if wrapped round with a single fold of thin flannel, closely adhering to the surface, as will be seen by the following simple experiment. A thin hollow cylinder of tin-plate, of 2 inches diameter and 5 inches in height, quite bright and clean on the outside, was filled with hot water, and a thermometer bulb introduced in the middle of the water through a hole in the cork which fitted to the top. The heat of the water observed every five minutes from 195° was, successively, 195°—187.5°—180°—173°. The same experiment repeated with every circumstance the same, except that the cylinder was closely wrapped round with a single fold of flannel, now gave 195°—186°—177.5—170°. So that in fifteen minutes the cylinder covered with flannel had lost 3 degrees more of heat than when uncovered. This is explained from the principle that the surface is changed from a metallic, to one of soft vegetable matter, which radiates heat with much more intensity: but if wrapped round with several folds of flannel loosely adhering, this encreased radiating power would be fully or more than counterbalanced by the greater difficulty which the enclosed heat would find in being conducted outwards through so great a thickness of a loose spongy material.

All that has been said about the power of surfaces to promote or retard the radiation of caloric from them when hotter than the surrounding air (and equally the absorption and reflexion of radiated caloric) apply exactly, changing the circumstances, to the radiation of cold, meaning by this term a temperature lower than that of the surrounding atmosphere. Thus iced water contained in a bright clean metallic vessel and exposed to a warm air, retains its cold longer (or, were cold, a positive substance we should say the metallic surface *propels frigorific rays* with less force) than if the outside of the vessel were painted or even tarnished. But this leads to the curious enquiry relating to

The Radiation and Reflexion of Cold.

Nothing appears at first sight more directly contradictory to the common opinion of cold being only relative, and only a negative term implying the abstraction of heat, than the facts which shew the apparent radiation, absorption and reflexion of cold; the evidence of which stands on the same ground as the corresponding motions of heat already described, namely, on the rise or fall of the thermometer. If the *rise* of the liquor on the scale of a thermometer whose bulb is placed in the focus of a mirror, be considered as a proof of the propulsion of certain calorific rays from a distant heated surface, and their subsequent reflexion according to the laws of catoptrics; the *sinking* of the same thermometer liquor under similar circumstances of position, when the surface which before was sensibly hotter than the atmosphere is now sensibly colder, would seem from a parity of reasoning to indicate the propulsion and reflexion of frigorific rays. Nor can we consider this question as at all determined, though an ingenious hypothesis has been advanced by M. Prevost, which goes a considerable way to reconcile the apparent contradiction of the doctrine of the unity of heat and cold. The leading facts however are the following.

It is singular that the reflexion of cold should have been accidentally discovered and decidedly announced about the year 1667 by the members of the Florentine Academy del Cimento, without any further prosecution of so curious a fact.

The experiment is the following.[l] A mass of ice of about 500 lb. was set some distance before a concave glass mirror, and the bulb of a spirit thermometer put in the focus to try whether cold would be reflected. Immediately the spirit of the thermometer began to sink, and fell several degrees. To prove that this was not merely owing to the contiguity of the ice, the surface of the mirror was covered with a cloth to prevent the reflexion, and the thermometer again rose. No further inference is drawn from this experiment, and the author of it seemed even to doubt of the reality of the reflexion, and to be disposed to impute it to some other unknown cause.

This experiment was repeated in a much more accurate way by M. Pictet.[m] The apparatus which he used was the same as that before described, as employed for the reflexion of heat; that is, two tin mirrors placed directly opposite each other at some distance, in the focus of one of which was placed the bulb of a very sensible thermometer, and in the other the

[l] Waller's Translation, p. 13. [m] Essai sur le Feu.

veſſel intended to produce the heat or cold. In this inſtance this latter was a matraſs full of ſnow: the mirrors were ſeparated to the diſtance of 10½ feet. At the inſtant the matraſs was placed in one focus, the thermometer in the oppoſite focus began to ſink, and deſcended ſeveral degrees. When ſtationary, nitrous acid was poured on the ſnow, which produced a cold of much greater intenſity, and the thermometer in conſequence immediately deſcended ſeveral degrees lower. When taken out of the focus, it again roſe to the common temperature.

Mr. Leſlie alſo found, not only the ſame effect in his experiment, but that the action of a cold-radiating ſurface upon the tin reflector produced exactly the ſame proportional effect upon the differential thermometer as the hot radiating ſurface, only in the oppoſite direction of the ſcale. The differential thermometer, which is always at zero when both bulbs are equally heated, is beautifully calculated to ſhew this ſtriking experiment. Thus if the difference of temperature between the heat-radiating ſubſtance and the atmoſphere be 60 degrees, and if this *raiſes* the thermometer 45 degrees, the ſame difference between the cold-radiating ſubſtance and the atmoſphere will *ſink* the thermometer 45 degrees, and ſo in proportion; ſo that a cold of 16 degrees will ſink the thermometer 12 degrees, for 60 : 45 :: 16 : 12.

The range of theſe experiments on cold is neceſſarily more limited than that of heat, for it is not eaſy to keep up a cold leſs than 0° (Fahr.) in any veſſel, for a moderate length of time, which is only about 60° below the average temperature of a room; whereas the heat of boiling water is 150° above this average. Beſides, a ſource of error takes place in eſtimating the propulſive energy of a cold ſubſtance when at a very low temperature, which is, the conſtant condenſation of the moiſture of the atmoſphere on the ſurface, except the air is uncommonly dry, and this introduces an extraneous ſubſtance into the comparative experiments.

The theoretical explanation of theſe curious facts leads us immediately to the conſideration of

The Equilibrium of Radiant Caloric.

The ſimpleſt explanation of what paſſes when a heated body cools in a cold medium and raiſes the temperature of the ſurrounding ſubſtances, is to ſuppoſe a mere efflux of caloric from the hotter to the cooler bodies, radiating with more or leſs force according to the greater or leſs difference between the thermometrical heat of the two, and the nature of the heated ſurface, with regard to its heat-propelling quality. This would explain without difficulty the reflexion of heat in the experiments already related, but would not apply with equal eaſe to the reflexion of cold. For ſuppoſing (as the ſimpleſt caſe) a caniſter filled with iced water at 32°, ſtanding before a tin reflector, and a thermometer bulb in the focus, with the common temperature of 60°; if no other radiation takes place than that from the hotter bodies to the colder one, the cold caniſter would merely make a kind of void or gulph, into which the thermometer bulb, the reflector, and the ambient air would all pour their exceſs of heat by direct radiation in the ſhorteſt path, and not in any other direction; nor could any retrogradation or reflexion of rays take place between the thermometer and the mirror. [a] Hence the preſence of the mirror could make no difference in the temperature of the thermometer, and its focal point would not be colder than any other contiguous ſpot.

The very ingenious theory of M. Prevoſt reconciles this difficulty without requiring the ſuppoſition of poſitive radiations of cold; though this laſt hypotheſis will certainly apply with equal force to all the circumſtances of the reflexion of cold as to thoſe of heat.

According to M. Prevoſt, [b] heat, when uncombined, is a ſubtile fluid, of extreme mobility, diſperſing its particles in every direction, which exiſt in that ſtate of mutual repulſion or ſeparation, that contrary or different currents may croſs each other, like thoſe of light, without diſturbance or interference. This conſtitution of heat being admitted, a conſtant interchange of radiations of heat is kept up between all ſubſtances placed within the ſphere of mutual influence, whether hot or (comparatively) cold. The interchanges are equal when the ſubſtances have the ſame thermometrical temperature, and the mutual *tenſion of heat* is then in equilibrium. A hot body, in cooling, parts with more caloric than it receives, and its exceſs of heat diſturbs the tenſion of heat between it and the ſurrounding bodies, till the inequality of the interchanges has reſtored the equilibrium. On the other hand a comparatively cold body, in heating, receives more caloric than it parts with, as long as the equilibrium is reſtoring.

To apply this hypotheſis to the two oppoſite experiments of the reflexion of heat and of cold.

Where (in the apparatus of Mr. Leſlie ſo often referred to) the caniſter is filled with boiling water, and therefore hotter than the ſurrounding air and the mirror, the interchanges

[a] Prevoſt, Ph. Tranſ. 1802. [b] Recherches Phyſico-Mechaniques ſur la Chaleur, & Ph. Tranſ. 1802.

of caloric are unequal, and (comparatively) hot rays proceed from the canister. As the rays from this quarter are the only ones which can produce any effect in the focus of the mirror, the temperature of the focus, like and superior in degree to the rays from the canister, is hot; and the thermometer proportionally raised. On the other hand, when the canister is filled with ice mutual interchanges of caloric take place, as before, between all the substances concerned in the experiment; but the rays that proceed from the canister are now (comparatively) cold, and hence a similar and more intense cold is produced in the focus, which is shewn by the sinking of the thermometer.

It does not appear that any experimental proof can be devised to confirm or disprove the truth of the above hypothesis of the constant and mutual radiations of caloric between substances whose thermometrical temperature is the same; since the thermometer is the chief, if not the only instrument, which we can apply to detect the passage of heat, and it is obvious that it only indicates the disturbance of the equilibrium, and not the mutual interchanges that maintain this equilibrium. The relation and correspondence between the powers of propelling and of absorbing caloric possessed by different surfaces, and so beautifully illustrated by Mr. Leslie's experiments, may perhaps be a support to the above hypothesis, since it reconciles the maintenance of the equilibrium of the conducted heat in liquids, however enclosed by vessels of any solid materials, and in solids themselves, with that of the radiant heat of the surrounding atmosphere.

The cooling of hot bodies by simple radiation into the surrounding cold medium, and the heating of cold bodies by absorption from the surrounding hot medium, are regulated by certain laws, which have been well explained by the experiment of M. Kraft and Richman. [p] The most important of these is the following. When a hot body is immersed in a cold medium of uniform temperature (in the common atmosphere for example) the loss of heat proceeds in an inverse geometrical progression, whilst the time proceeds in a direct arithmetical progression. The same rule also applies to the heating of a cold body in an uniformly hot medium. For instance, supposing the propulsion of caloric from the heated body is of such an intensity that one-tenth of the whole excess of heat, above that of the surrounding medium, is lost in one minute; then, at the end of that time there will remain $\frac{9}{10}$ of the whole. After the second minute, the tenth of the heat that was left is dissipated, and hence there now remains in the heated body $\frac{9}{10}$ of $\frac{9}{10}$ or $(\frac{9}{10})^2$. After the third minute there will remain $\frac{9}{10}$ of $(\frac{9}{10})^2$ or $(\frac{9}{10})^3$. After the fourth minute $(\frac{9}{10})^4$, and so on, the quantity of heat decreasing in geometrical progression, whilst the time encreases in arithmetical progression.

Hence too it appears that whilst the equilibrium of heat is restoring, the actual quantity of caloric passing from the hotter to the colder body is constantly decreasing in equal times: thus if the first excess of heat be equivalent to 100, the first minute will subtract 10, the second minute 9, the third 8.1, the fourth 7.29, and so on in proportion, always leaving $\frac{9}{10}$ of the last residue. Hence, after 10 minutes have elapsed (at which time the whole excess of heat would have been spent, had the actual loss been uniformly the same as during the first minute) more than one-third of the original 100 parts, or 34.86 parts, still remain in the heated body. This encreasing slowness of heating or cooling, as it approaches the equilibrium, is a matter of common observation in numberless experiments. Thus if a thermometer be plunged in boiling water and then exposed to the air, it will sink at first visibly and rapidly, but this sinking will soon be found more and more retarded, and at last many minutes will elapse before it has arrived at the exact temperature of the air. The same of cold bodies, in acquiring the heat of the surrounding medium.

The same reasoning will apply to the hypothesis of the mutual interchange of caloric between bodies, whatever be their thermometrical temperature. For if a cold body is exposed to a hot medium, the heat of this last may be considered as divided into two parts, that which is equal to the cold body, and that which forms the excess. With regard to the first, as it only serves to equalize what it receives from the cold body, and to produce an equilibrium, it is put out of the question, and it is only the excess to which the laws of progressive diminution can be applied. [q]

The investigation of the above law of Richman becomes somewhat more complex when both the hot and the cold body are changing their temperature, the former by losing, the latter by gaining caloric; for in the heating or cooling of any substance in the atmosphere, the proportion between the bulk of the body and the medium

[p] N. Comm. Acad. Petrop. [q] Prevost.

in which it is immerſed is ſo ſmall, that in moſt inſtances the temperature of the medium may be conſidered as ſtationary.

Though the radiation of caloric generally takes place in the medium of the atmoſphere, and certainly neither in denſe fluids nor in ſolids, it does not appear that any medium is neceſſary to convey the radiations of heat. Certain it is that according to apparently accurate experiments, caloric does paſs directly through the torricellian vacuum, though it is phyſically impoſſible to confine a thermometer bulb within a vacuum without ſome neceſſary communication with the external apparatus through the ſtem of the inſtrument, ſo as to be able to convey heat by a different path than that of radiation. It appears that caloric is capable of radiating through a vacuum, when the ſides of the veſſel that forms the vacuum have a higher temperature than the vacuum itſelf, or than any ſubſtance placed in it; or vice verſa, when the encloſed ſubſtance is hotter than the ſides of the confining veſſel. Count Rumford's experiments on the comparative conducting power of air and a vacuum are much to the point.[r]

Count Rumford very judiciouſly rejected the common air-pump receivers, as it is well known that none will enſure a perfect vacuum, both on account of the impoſſibility of rigorouſly exhauſting all the air, and becauſe of the watery vapour which always ariſes from the moiſture and the oil of the apparatus, and which, like rarefied air, is a conductor of heat. He therefore employed the torricellian or barometical vacuum, and by ingenious management ſoldered the ſtem of a thermometer tube into that of a glaſs bulb, which formed the vacuum, ſo that after filling with mercury, inverting the tube, and fuſing together with a blowpipe the two ſtems, a compleat inſulated vacuum was left in the larger glaſs ball, with the bulb of a fine thermometer encloſed in the centre.

This apparatus was then immerſed in warm water of a certain temperature to become uniformly heated, and then taken out and ſuddenly plunged in water at the boiling point, and kept at this heat during the whole of the experiment. The conſequence was a gradual but ſlow riſe of the encloſed thermometer during the whole time of immerſion. The minute particulars need not be related, it is ſufficient to obſerve that from 72.5° it roſe in 1 min. 30 ſec. to 81.5, in 4 min. to 133°, and in 5 minutes to 141°. On admitting air to the ſame apparatus and repeating the immerſion, the thermometer now roſe to the ſame points in a much ſhorter time, requiring reſpectively only 45 ſec., 2 min. 10 ſec., and 2 min. 40 ſec.

The ſame kind of experiments were repeated with a more delicate apparatus, in which the communication between the thermometer and the external part of the apparatus was only a ſilk thread, and ſtill the external heat arrived at the encloſed thermometer through the vacuum in progreſſive ſteps, and by reverſing the experiment the acquired heat eſcaped from the thermometer to the external air.

By a conſiderable agreement of ſeveral experiments, Count Rumford concludes that the conducting power of a vacuum compared with that of the ſame extent of air perfectly at reſt, is as 702 to 1000 nearly; for in the above experiments the quantity of heat communicated being equal, the intenſity of the communication is inverſely as the times.

But, as will be ſeen in the next ſection, it is difficult to make an eſtimate of the true conducting power of air diſtinct from that of the intenſity with which caloric radiates through this medium, and therefore theſe experiments are only ſatisfactory as to the leading facts that caloric will paſs through a vacuum, though with leſs rapidity than through air. It would be an intereſting ſubject for experiment (though not eaſily managed) to aſcertain how much the nature of the propelling ſurface affects the radiation of heat through a torricellian vacuum.

Of Conducted Caloric.

All bodies in nature are pervious to caloric, for no ſubſtance has ever been diſcovered which will for any length of time retain or confine that modification of heat and of cold which is ſenſible to the feelings and to the thermometer. But caloric is found to *radiate* through no other medium than the aeriform, conſequently its paſſage through ſolids and liquids muſt be performed in a different manner; and even through air it does not entirely paſs by radiation, ſince the ſtate of the air as to denſity, moiſture, motion, &c. is found to make a very decided difference in the eaſe with which heat pervades it.

When heat combines with any ſubſtance, the firſt effect is to expand it in every dimenſion, and this law is ſo univerſal as not to have a ſingle proper exception. When any portion of a ſolid body is expanded, the only effect can be to produce a mutual receſſion of the particles acted on, and not a diſplacement of their comparative juxta-poſition. If a perpendicular bar

[r] Ph. Tranſ. 1786.

of metal were made, the upper half of iron, and the lower of copper, and heat applied from beneath, no expanſion of the lower portion could cauſe a mixture of the two metals, or a paſſage of one through the other. But quite the reverſe happens when a liquid or gaſeous body is partially heated; for being compoſed of fluid particles of great mobility, thoſe that receive the firſt impreſſion of heat and become expanded by it, acquire thereby a comparative levity, their ſpecific gravity being diminiſhed, and, if at the lower part of the maſs, they immediately riſe through the cooler portion to the ſurface, giving off in their paſſage more or leſs of their acquired heat to the particles of the cooler fluid with which they ſucceſſively come in contact.

This eſſential difference in the mode of communication of heat renders it neceſſary to conſider ſeparately its paſſage through ſolids; and it would be even convenient in philoſophical language to diſtinguiſh theſe very different motions of caloric by appropriate terms.

Of the Propagation of Heat in Solids.

When a ſolid body (a bar of metal for example) is expoſed to the influence of any ſource of heat, this laſt pervades the metal, not with the immeaſurable velocity of radiant heat, but with a ſlow and gradual progreſs, from the neareſt to the moſt remote part; and if the heat be below fuſion, producing no other apparent effect than expanſion, and a ſomewhat different degree of cohefion of the particles of the metal. As radiant heat may be conſidered as caloric in its ſtate of the greateſt freedom, and the moſt uncombined, and as then it is found to move with a velocity utterly incalculable by any experiment, it muſt follow that the extreme retardation of its motion in paſſing through a ſolid is owing to a ſucceſſive combination with all the particles or ſtrata of particles which oppoſe its progreſs. Hence the particles of ſolid matter muſt have an affinity for caloric to be able to detain it for (comparatively) ſo great a length of time; and as this time is in no degree regulated by the ſpecific gravity or denſity of the ſolid, that is by the ſuppoſed number of integrant particles of which it is compoſed, it ſeems evident that each ſubſtance has its peculiar and relative force of affinity with caloric. This force of affinity is obviouſly in direct oppoſition to its conducting power, for the greater force it exerts in detaining caloric, the leſs eaſily will it conduct, or allow the paſſage of caloric through its ſubſtance. Hence too the terms *good* or *bad conductors*; the former term being applied to thoſe bodies that have the weakeſt affinity for heat; the latter, to the ſtrongeſt.

The paſſage of conducted heat through a body has its limits. Owing to the affinity between the two, a certain portion of the caloric is detained within the ſubſtance heated, and the expanſion produced by the combination ſeems to aſſiſt in this detention. We in fact find that if one end of a very long bar be heated moderately and for a ſhort time only, the heat is ſenſibly conducted only to a ſmall diſtance, and in a conſtantly diminiſhing intenſity. There is no good reaſon however to ſuppoſe that any of the acquired caloric is permanently detained in the bar, after the heated end has returned to the common temperature and the whole has contracted to its original dimenſions. The intenſity of conducted heat, and the diſtance to which it may be propagated, are alſo determined by the temperature at which the ſubſtance begins to melt, conſume, or to undergo any other chemical change; for when this occurs, all the ſurplus heat above this point is employed in the chemical changes that are going on, and does not materially add to the quantity that paſſes off by the conducting power. Therefore (other things being the ſame) an indefinite intenſity of heat will paſs to a greater diſtance through a leſs than a more fuſible metal, and further through an incombuſtible than a combuſtible ſubſtance.

Though caloric is capable of paſſing through ſolids in every direction, it appears that it more readily proceeds upwards than downwards. The experiments of M. Pictet confirm this opinion, which has long been entertained. The apparatus employed by this very able experimenter was a glaſs tube about 4 feet long, containing a cylindrical bar of copper, hollowed a little at top and bottom, to receive the bulbs of two fine thermometers. The bar and tube were ſuſpended vertically, and the bar was heated exactly in the middle by the ſun's rays thrown upon it, and the exact ſpot was ſecured by encloſing the whole apparatus in a wooden frame, perforated at the place on which the heat was to fall. Moreover the glaſs was exhauſted of its air, to a trifling reſidue, by a good air-pump, otherwiſe the mere aſcent of the heated air in contact with the copper bar would certainly heat the upper part ſooner than the lower, and defeat the object of the experiment. On heating the middle of the bar and obſerving the times required to raiſe the touching thermometers to the ſame heights, it was found that the upper one was conſiderably ſooner heated than

the lower, and on changing the thermometers, that which was now at the top of the bar roſe the higheſt in equal times as before. Alſo on obſerving the comparative rates of cooling, the difference was ſtill more ſtriking; for whilſt the lower thermometer rapidly cooled, the upper one for ſome time did not ſink at all, its loſs of heat being exactly balanced by the influx from the lower part of the bar.

The above experiment cannot be conſidered as quite accurate, as no air-pump vacuum is a perfect one, and even if free from air it ſtill contains ſome vaporous moiſture, which is itſelf a conductor of caloric; and therefore the ſource of error intended to be avoided by the air-pump is not entirely removed. Another difficulty ariſes from the extreme difficulty of enſuring exactly the ſame extent and accuracy of contact of the upper and lower thermometer bulbs with the ſolid copper bar; but with all theſe deductions we may ſtill conſider it as nearly certain that caloric is more readily conveyed through ſolids in an upward than in any other direction. In the ſame apparatus another upper and lower thermometer were ſuſpended, ſo as nearly, but not quite, to touch the heated metal, and therefore were inſulated in a vacuum. The great ſluggiſhneſs of their riſe and fall, compared with the two that actually touched the heated bar, ſhewed (what has already been mentioned) the difficulty with which caloric radiates through a vacuum.

Metals are by far the beſt ſolid conductors that we are acquainted with. Every one knows that if one end of a ſhort ſlender iron rod be thruſt in the fire, the other end ſoon becomes intolerably hot to the fingers; whereas the ſame length of a ſimilar wooden rod may be held without any inconvenience, and may even be conſumed to within nearly a quarter of an inch of the fingers that hold the other extremity without burning them. The comparative conducting power of different ſubſtances is ingeniouſly ſhewn in the following way. Take ſhort thin rods, of equal ſize and length, of any of the different metals, of glaſs, and any other ſubſtance required; coat one of the ends by dipping it into melted wax or tallow, and immerſe the other into boiling water, or any other hot medium to which they will all be equally expoſed. After a while the wax will melt, firſt from the metallic rods in the order of their conducting power, then from the glaſs or other ſubſtance uſed, and the comparative times required to melt the wax from the reſpective rods will give their comparative conducting power.

In this manner Dr. Ingenhouz [s] found the comparative conducting power between ſeveral metals to be in the following order: ſilver, gold; copper and tin nearly equal; platina, iron, ſteel and lead, all much inferior to the others. Hence the conducting power by no means correſponds with the denſity, tenacity, oxidability, fuſibility, or any known quality common to all metals.

Next to metals, ſtones, glaſs, and hard earthy ſubſtances or compounds appear to have the greateſt conducting power.

The conducting power of ſeveral woods has been aſcertained with apparent ſkill and accuracy by Mayer, profeſſor at Erlangen. [t]

Balls of the different woods were turned of the ſame diameter, and hollowed out ſo as juſt to admit the bulb of a fine thermometer. Theſe balls were firſt dried in a gentle ſtove-heat for ſeveral days, and then heated uniformly to a certain point, and brought into a cold room without a fire. The reſpective times taken by each ball to cool to certain fixed points indicated inverſely their comparative conducting power. A correction became neceſſary however on account of the unequal ſhrinkage of the balls during the drying. This was eaſily calculated from the law that in veſſels of the ſame ſubſtance the comparative time of heating or cooling is at the diameter of the veſſel. The balls being thus reduced by calculation to the ſame dimenſions, the times of cooling from one given point to another were determined by the number of vibrations of a pendulum, which of courſe would be inverſely as the conducting power. Elm wood was taken as a ſtandard, to which all the others were firſt referred, and afterwards referred to that of water, whoſe conducting power was found by confining it in a hollow glaſs ball of the ſame dimenſions as the wooden one, and deducting the ſeparate effect of the glaſs. The ſpecific gravity of the different woods was alſo aſcertained, which is worth notice, as it ſhews ſome kind of accord between it and the conducting power, inverſely, though not with much proportional accuracy.

[s] J. Phyſ. tom. 34. [t] An. Chim. tom. 30. from Crell's Journal, 1798.

The following is the comparative table:

	Conducting power.	Specific gravity.
Water	10.	1.000
Ebony wood	21.7	1.054
Apple-tree	27.4	0.639
Aſh	30.8	0.631
Beech	32.1	0.692
Hornbeam	32.3	0.690
Plumb-tree	32.5	0.687
Elm	32.5	0.646
Oak	32.6	0.668
Pear-tree	33.2	0.603
Birch	34.1	0.608
Silver fir	37.5	0.495
Alder	38.4	0.484
Scotch fir	38.6	0.408
Norway ſpruce	38.9	0.447
Lime	39.0	0.408

It will be ſeen by inſpecting the above table that the order in which they are given is directly as the conducting power, and inverſely as the ſpecific gravity, ſo that the lime, for example, which is leſs than half the weight of the ebony, has nearly twice the conducting power; which being inverſely as the times, it follows that if 39 portions of time are employed in the paſſage of a certain quantity of thermometrical heat through ebony wood, only 21.5 ſimilar portions of time would be required to conduct the ſame quantity of heat through an equal bulk of lime tree wood.

Theſe reſults, if accurate, are very curious, for it is commonly obſerved that, *ceteris paribus*, ſubſtances of a light porous texture are worſe conductors of heat than thoſe that are denſe and cloſe-grained; whence we may infer (what indeed has been obſerved by Count Rumford and other philoſophers) that mere poroſity of texture is not neceſſarily connected with a retardation of the paſſage of heat, but in as far as it allows of the detention and adheſion of numerous particles of air, which elaſtic fluid, when at reſt, is known to be one of the worſt conductors in nature. Now it does not appear that the lighter woods contain more interſtitial air than the heavier.

The intereſting experiments of Count Rumford on the conducting power of various animal and vegetable ſubſtances uſed in cloathing, and on the natural coverings of animals, may here be ſhortly mentioned. [u] The inſtrument employed was very ſimple; it conſiſted of a mercurial thermometer, divided according to Reaumur into 80 degrees from freezing to boiling water, and incloſed in a large glaſs tube, with a bulb of the ſame ſhape with the thermometer, but wide enough to allow of about an inch of vacant ſpace on all ſides between the two. The upper end of the thermometer paſſed through a hole of the ſame cork which cloſed its inveſting tube, and which kept it fixed in its proper ſituation, at the ſame time that the air contained in the interſtitial ſpace was by this means preſerved at reſt. The ſpace between the two was the place in which the various ſubſtances for experiment were introduced, and their conducting power was aſcertained by the time at which the thermometer, previouſly heated to 75 of the ſcale, fell to determinate points when expoſed to a cold atmoſphere. Thus ſituated, it is obvious that the ſubſtances introduced in the intermediate ſpace between the two glaſſes would retard the ſinking of the thermometer in inverſe proportion to their power of conducting heat; and when in the comparative trials, equal points of the thermometer were taken, the times required to ſink to theſe given points would give reſpectively the inverſe conducting power of the ſubſtances under experiment. It is to be obſerved that part of the communication of heat, both from the thermometer to the outer glaſs, and from this laſt to the external air, was made by radiation, but in theſe experiments no material ſource of error probably aroſe from this circumſtance. The ſubſtances introduced were puſhed down by a braſs wire, and diſtributed as equally as poſſible through the vacant ſpace. The conducting power of this ſpace, that is of the atmoſpherical air filling it, was firſt aſcertained as a ſtandard of compariſon. The ſubſtances employed were raw Silk, Sheep's Wool, Cotton Wool, fine Lint, Beaver's Fur, Hare's Fur, and Eider Down, and the quantities of each were of equal weight. But the times required for the cooling of the thermometer ſurrounded with each of theſe ſubſtances were much more equal than was expected, therefore we ſhall only give the two the moſt differing, and air which was the ſtandard.

Heat loſt.	Air.	Fine lint 16 grains	Eider down 16 grains.
70°	—	—	—
60°	38″	80″	98″
50°	46	93	116
40°	59	115	146
30°	80	150	192
20°	122	218	268
10°	231	376	485
	576	1032	1305

[u] Ph. Tranſ. 1792.

Hence it appears that when a heated thermometer ſurrounded by about an inch in thickneſs of confined air takes 576 ſeconds to cool 60 degrees of Reaumur (135° Fahr.) it will take 1032 ſeconds to cool to the ſame point when 16 grains of lint are diffuſed through the confined air, and 1305 ſeconds when the ſame weight of eider down is uſed; ſo that, as the conducting power is inverſely as the times, if the power of air be reckoned as 1000, that of the lint will be 558, and of the eider down 441.

But lint, eider down, fur, and ſimilar flocculent ſubſtances may be conſidered as ſo many compounds of fine ſolid matter, with air inſeparably adhering to them, and filling all their interſtices, and their true conducting power, diſtinct from that of the air they contain, cannot be determined by ſuch experiments as theſe above related.

The conducting power of theſe ſubſtances is further diminiſhed by the cloſeneſs with which their particles are heaped together, at leaſt to a certain limit, provided this compreſſion does not proceed to alter their texture, which again would have a contrary effect. Thus Count Rumford found that when the ſame ſpace which in the above experiment was occupied by 16 grains of eider-down, was filled, firſt with 32 grains, and then with 64 grains, the times employed in the paſſage of the 60 degrees of heat were ſucceſſively encreaſed from 1304 ſeconds to 1472", and 1615".

On the other hand, to ſhew the effect of mere *texture*, ſimilar comparative trials were made of the conducting power of equal weights of raw ſilk, of ravelings of white taffeta, and of common ſewing ſilk, of which the firſt has the fineſt fibre, the ſecond leſs fine, and the third, from being more twiſted and harder, is much coarſer. The difference between theſe three modifications of the ſame ſubſtance is very ſtriking, the raw ſilk detaining the heat for 1284 ſeconds, the taffeta ravelings 1169", and the ſilk thread only 917".

Hence as a general inference it may be obſerved that, as far as the mere conducting power of animal and vegetable fibre is concerned the ſubſtances that detain heat (or cold) the longeſt, that is, that have the leaſt conducting power, or are the *worſt conductors*, are thoſe in which the fibres are the fineſt and the moſt condenſed, provided that this condenſation does not amount to that degree which would expel the interſtitial air. But again, the ſurface immediately in contact with the outer air, parts with heat largely by radiation, as well as by the true conducting power of air, and therefore the ſuperior power of propelling caloric poſſeſſed by unequal and ſoft ſubſtances, over thoſe that are hard, ſmooth, and poliſhed, and which acts quite in a contrary way to the conducting power, muſt always be taken into conſideration.

Of the Conducting Power of Air.

It has been already obſerved that when a heated ſubſtance is freely expoſed to the air (or any aeriform medium) it parts with its exceſs of heat very largely by *radiation*, which is more or leſs intenſe according to the degree of the exceſs of heat, the nature of the ſurface in immediate contact with air, and the like; but radiation is not the only way in which heat is loſt, for much of it paſſes off by the conducting or more properly the *carrying* power of the air itſelf. This is amply proved by the vaſt effect which agitation of the air produces in encreaſing the rapidity of cooling, which is readily explained by ſuppoſing that the particles of cold air when they come ſucceſſively in contact with the heated ſurface, abſorb part of the heat, and thus convey it away into the diſtant atmoſphere. This kind of conveyance of heat therefore differs both from radiation, which is propagated to an immenſe diſtance in an inſtant of time, and from the ſlow and ſucceſſive mode in which heat is conducted through ſolids, pervading particle after particle, and as it were ſaturating one ſtratum of particles before it proceeds to the next. Here on the other hand (and the ſame with liquid mediums) as the heat is conveyed along with the particles of the air with which it unites, its motion is preciſely that of theſe particles, faſter or ſlower according to the degree in which it expands them, and the buoyancy which it thus imparts, and alſo according to the force of any other propelling power which the air may have received. We ſhall find therefore that cool air conveys heat from a hot ſurface in direct proportion both to the rapidity with which it is renewed, and to its coldneſs when it ſtrikes the heated body.

The cold produced by ſweeping winds is a matter of common obſervation, but it is better to have recourſe to direct experiment. The following is eaſily performed. Fill a glaſs matraſs, or any other veſſel whatever, with boiling water, introduce a thermometer, and ſimply put it in the body of a blaſt furnace (without fire) and obſerve the point to which it cools in a given time. Afterwards repeat the obſervation with the ſame veſſel, in the ſame ſituation, and with no other difference but that of working the bellows during an equal time, and the

difference of cooling will be very ſtriking. In the former caſe if the water cools from 188° to 180°, by ſimple expoſure for five minutes, it may be ſunk in the latter caſe from 188° to 170° by a ſtrong blaſt for the ſame time. The compariſon will be better if inſtead of equal times, equal loſſes of heat are obſerved, and then the comparative rate of cooling will be inverſely as the times. Now there is no reaſon to doubt that the radiation from the hot ſurface is the ſame in both circumſtances, and therefore the difference muſt be owing to the ſuperior quantity of caloric conveyed away by the rapid motion of the air.

We find too that air has no cooling or heating effect on a *dry* ſurface, unleſs it be colder or hotter than the ſubſtance on which it plays. Thus if the bulb of a thermometer of the temperature of the ſurrounding air be wiped perfectly dry, and the ſtream from a bellows be directed on it, no riſe or fall of the mercury enſues: but on the other hand a ſtream of warm air directed on a piece of ice will melt it much faſter than ſimple expoſure to an equally warm atmoſphere. In all theſe caſes the ſubject of experiment is ſuppoſed to be *dry*, for if moiſture be preſent, the encreaſed evaporation produced by an augmented velocity of air will at all times abſtract a large portion of heat, as will be further explained.

Mr. Leſlie's experiments on this ſubject are curious and preciſe. A thin hollow globe of bright tinned iron, drawn into a fine neck through which a thermometer was inſerted, was filled with hot water, and ſuffered to cool to a certain point without diſturbance in a cloſe room without a fire, the temperature of which was perfectly ſteady. The ſame experiment was repeated with no other difference than that the outſide of the veſſel was covered with black paint, the effect of which (as mentioned under the head of radiant caloric) would be to encreaſe, to about eight times, the energy of the caloric radiated from the ſurface, the ſame being aſcertained by the effect of the reflection of radiated caloric from a diſtant concave tin reflector. The bright ball actually cooled to a given point in 156 minutes, whilſt the painted ball cooled to the ſame point in only 81 minutes. The difference between theſe two numbers is ſufficiently ſtriking, but very far ſhort of what would have happened had the loſs of heat been occaſioned by mere radiation, ſince the effect of this latter is eight times more in the painted than the metallic ſurface, whereas in this caſe it is only about double. Therefore when a heated ſubſtance is expoſed to a free atmoſphere, though as much at reſt as a cloſe room and an equal temperature will enſure, a large portion of the cooling effect is to be attributed to the conducting power of the ſurrounding air and the motion excited in it by the heated body itſelf, as well as the radiating power.

An encreaſe in the motion of the air ſtill further illuſtrates this. The ſame bright tin ball, and another ſimilar ball, painted, were expoſed in the evening (when the heating effect of the atmoſpherical reflection would be ſcarcely felt more on the black than the metallic ſurface) to the action of a gentle wind out of doors under perfectly ſimilar circumſtances. The ſame loſs of heat as in the former experiment was now produced in the bright ball in 44 minutes, and in the painted ball in 35′. A pretty ſtrong breeze in another experiment reduced the reſpective times to 23′ and 20¼′. A vehement wind brought them ſtill further down to 9½′ and 9′. Theſe comparative experiments, and the inferences deduced from them by calculating the entire range of cooling on the ſuppoſition of an uniformly equal loſs of heat, [*] point out two important circumſtances, the one, that the actual rate of cooling is moſt materially affected by the motion of the air; and the other, that the more rapid the motion of the air is, the leſs is the comparative effect of the nature of the heated ſurface: or in other words, that the proper conducting power of air acts apparently with equal energy on all ſurfaces, and therefore by abſtracting heat ſo powerfully it uniformly diminiſhes, and finally renders almoſt inſenſible the peculiar differences of the radiating proceſs. The above experiments will be better ſeen in a tabular form.

An equal loſs of heat was experienced by the

minutes.		minutes.	
bright ball in 156	and by the painted ball in 81		(which is as 1000 : 519) in a cloſe room.
44		35	(1000 : 795) in a gentle breeze.
23		20¼	(1000 : 880) in a ſtrong breeze.
9½		9	(1000 : 947) in a violent wind.

[*] Leſlie, p. 268.

Where the temperature of the heated body is much above that of the cold medium, a ſimilar effect is produced to that of agitating the air, that is, in tending to encreaſe and at the ſame time to equalize the rate of cooling of the oppoſite ſurfaces of metal and paint. In fact an actual encreaſe of agitation in the air is thereby produced, ſince the operation of any hot body muſt be to cauſe a conſtant aſcending current of hot, and therefore light, air, in proportion as it receives caloric by contact with or proximity to the ſource of heat; conſequently, the greater the degree of poſitive heat, and the more rapid will be the current of air.

It is alſo obvious that the ſame effect of encreaſing the ſucceſſive contacts of air is produced by agitating the heated body in ſtill air, as by agitating the air againſt the heated body when at reſt. Hence the common practice of haſtening the cooling of any ſubſtance by waving it backwards and forwards, and it appears that the refrigerant power of air is always (other circumſtances being the ſame) in exact proportion to its velocity.

The conducting power of air is diminiſhed by rarefaction, ſo that whatever has a tendency to dilate air, proportionally leſſens its power of conveying caloric. This diminution proceeds regularly till a compleat vacuum is formed, which, as already mentioned, is a ſtill worſe conductor of heat than any kind of air, however dilated. Every ſubſtance which when converted to vapor produces a dilatation of the air with which it combines, alſo diminiſhes its conducting power. Thus alcohol, ether, and even aqueous vapor diffuſed in air render it a worſe conductor than before. On the other hand, a condenſation of air obviouſly encreaſes its conducting power. It alſo appears that many of the permanent gaſſes have their peculiar conducting power, [w] independent of extraneous vapour or dilatation.

Much remains to be done on the ſubject of the propagation of caloric through gaſeous bodies, and the experiments neceſſary to purſue this inquiry are complex and difficult. At leaſt four diſtinct calorific actions muſt be preſent in experiments of this nature, and the diſtinct power of each muſt be aſcertained before any accurate concluſions can be drawn. One of theſe is the radiation of caloric from every heated ſurface when in contact with air; and as in all experiments veſſels muſt be employed to confine the air examined, and thermometers to eſtimate the paſſage of heat, the radiations from theſe ſolid bodies, and the propulſive energy belonging to the nature of their ſurfaces muſt be ſeparately conſidered. Another circumſtance to be conſidered is the denſity of the air examined, and its degree of moiſture, both of which affect the paſſage of heat. A third is the motion of the particles of air produced, even in cloſe veſſels, by the partial application of heat, cauſing, as already explained, an aſcending current over the heated body, of more or leſs velocity according to the difference of temperature between it and the ſurrounding medium. Beſides theſe, it is probable that air has a proper *conducting* power diſtinct from its *conveying* power; that is, that even if its particles could be kept at reſt on the partial application of heat, caloric would paſs through its ſubſtance, as it does through a ſolid, and through every natural body hitherto known. But this diſtinction between the conducting and the conveying power will be more clearly pointed out in the following ſection.

Of the Conducting Power of Water.

In examining the propagation of caloric through water, radiation is totally out of the queſtion, it having been fully proved that heat does not radiate through a denſe liquid medium. Neither can the circumſtance of rarity or denſity produced by external preſſure ſenſibly affect an inelaſtic fluid; but only the change in ſpecific gravity produced by the ſimple addition or abſtraction of caloric. The enquiry is therefore much ſimpler than that of the paſſage of caloric through an aeriform medium, and is principally confined to theſe two objects, namely, the caloric which is *conveyed* through a maſs of water by the aſcent of the hotter particles, and the conſequent deſcent of the colder ones; and the caloric which is *conducted* through water in any direction, and principally downwards, independant of the internal motions of its particles.

A number of facts of daily occurrence ſhew the almoſt impoſſibility of heating water or any other fluid effectually by applying heat on the ſurface, and the comparative eaſe with which it receives heat from the bottom. Thus it muſt often have occurred to chemiſts to obſerve in the proceſs of diſtillation with a ſtill and worm-pipe paſſing downwards through a tub of water in a ſpiral direction, that the upper part of the water which is in contact with the hotteſt portion of the pipe ſoon becomes ſcalding hot and continues ſo for a long time, whilſt the lower part of the ſame water remains cold for many hours. But this principle was firſt more diſtinctly

[w] Leſlie.

examined by Count Rumford, whose beautiful experiments on the propagation of heat in fluids[x] rank with the most ingenious researches in natural philosophy.

It may be laid down as a general law, that when any portion of a fluid is heated above the common temperature of the contiguous mass, the hot particles immediately expand, and in so doing become specifically lighter than the rest; and therefore, if the heat is applied at bottom, the warmer fluid rises through the whole mass to the surface, giving off however on every side a portion of its excess of heat to the cooler liquid during its passage. But if the heat is applied at the surface, the upper part alone becomes heated, and being specifically the lightest it can only remain at the surface, and never comes in contact with the lower part of the mass, and consequently it cannot *convey* or *carry* caloric to it as in the former case. Many striking experiments, easily performed and perfectly convincing, prove that this is by much the principal method in which fluids become heated or cooled, so that for all general purposes it may be assumed to be impossible to propagate heat downwards or cold upwards in fluids without the assistance of mechanical agitation. Were this law absolute, it would follow that fluids are perfect *non-conductors* of caloric, since the conducting power implies the passage of caloric through successive particles or strata of bodies, and not the conveyance of caloric by the assistance of the movements of the heated bodies themselves.

Many are the experiments that shew the carrying power of heated fluids and the ascent of the heated particles. Thus if a quantity of hot water is poured into a jar of cold water through a long funnel touching the bottom of the vessel, the hot water will rise almost immediately to the top, encreasing the temperature of the whole mass in its passage. But if on the other hand cold water is poured down in the same manner into a vessel of hot water, it remains at the bottom, scarcely mixing with the hot, the surface of which will not have its temperature sensibly lowered for a considerable time.

The melting of ice under different circumstances of position is adduced by Count Rumford as a striking illustration of this principle. A piece of ice was fashioned so as to fill pretty closely about $3\frac{1}{4}$ inches in diameter of a tall cylindrical glass jar. Boiling water was first poured into the jar, and when nearly full the ice was dropped in, and melted *on the surface* of the hot water in 2 minutes 58 seconds. The experiment was then repeated with this difference, that the ice was first fixed to *the bottom* of the jar by two thin slips of deal, a very small quantity of cold water poured on it to fill the interstices, and boiling water poured upon the whole. In this last experiment the circumstances were so different that in more than double the time in which the former ice had entirely disappeared, the latter shewed not the least disposition to melt. The temperature of the water being taken at different heights, during several intervals for two hours, it was found that in all the trials the bottom of the water (or the part immediately resting on the ice) was uniformly 40°; but near the surface of the water, or seven inches above the ice, it was found at intervals of from 15 to 30 minutes, to have fallen to 160°, 149°, 131°, 117°, and at the end of two hours to $108\frac{1}{2}°$. At three inches above the ice the temperatures at the same periods were respectively, 159°, 148°, 128°, 116°, and finally 106°. During this long period, at the end of which the surface of the hot water was still 108°, it was found that full half the ice remained unmelted, so that the thawing had been full eighty times slower than when the ice was at the surface; and as it would have continued to go on still slower, many hours would doubtless have elapsed before the whole was melted.

This leading experiment, without entering into the particulars, shews in a most striking manner the effect of situation in heating and cooling fluids, and fully proves that the equal diffusion of heat through fluids is chiefly owing to the carrying power, or the motions occasioned by the inferior specific gravity of the hotter compared with the colder part of the same fluid.

A similar experiment[y], but still more striking, is the actual boiling of water over the surface of ice for a length of time, without melting any considerable portion of it; and in a general way, no experiment that could be devised illustrates more remarkably the extreme difficulty of the passage of heat downwards through dense fluids. It is thus performed. Take a thin long glass jar or tube closed at one end, fill about three inches of its height with water, and freeze it into a very solid mass, fast adhering to the bottom of the jar. This is done by immersing the jar in a mixture of salt and snow, till the ice within is quite firm and hard. Then take it out, pour on the ice about two or three inches of ice-cold water, and wrap the outside of the jar with several folds of flannel to the level of

[x] Essays. [y] Rumford's Essays.

the ice. Hold the jar by the end ſo covered at an angle of about 45°, and bring that part of it which is at the height of the ſurface of the water over the flame of a lamp or candle. When the ſurface begins to boil, ſlowly raiſe the tube ſo as to heat the lower part of the water, and thus, by avoiding to give a direct heat to the ice itſelf, the whole water will be ſeen to boil within a quarter of an inch of the ice. This ebullition may be continued ſeveral minutes before any ſenſible portion of the ice will be melted, except a ſmall part of the upper portion, which is furtheſt from the flame, and on account of the inclination of the jar, riſes above the level of the bottom of the water; ſo that after a time the ſurface of the ice is brought by melting to be nearly parallel with that of the water above.

If a jar be uſed, the heat of an Argand lamp will be required; and then a piece of wood or paſteboard ſhould be interpoſed between the cold part of the jar and the glaſs chimney of the lamp.

It has been already mentioned that light flocculent ſubſtances incloſed in a ſtratum of air, very materially retard the paſſage of heat through it, probably by embarraſſing thoſe mutual motions of the hot and cold particles whereby the heat is conveyed from place to place. Count Rumford alſo found a ſimilar effect to take place in *water* when mixed with ſubſtances either that gave it viſcidity by diſſolving in it, or that mechanically thickened it without actual ſolution. In the former caſe ſtarch was employed, in the latter eider-down, as in the experiments on the conducting power of air. The general reſult of the experiments was the following: when pure water took only 597 ſeconds to heat from 32° to 200°, a *ſolution* of 192 grains of ſtarch in 2276 parts of water, placed in preciſely ſimilar circumſtances, took 1109 ſeconds to acquire the ſame degree of heat; and a *mixture* of 192 grains of eider-down diffuſed in the ſame quantity of water, took 949 ſeconds. Applying this fact to culinary purpoſes it accounts for the great length of time in which thick half-fluid ſubſtances retain their heat.

It was alſo found that encreaſing the quantity of eider-down in a given ſtratum of air encreaſed the obſtacle to the tranſmiſſion of heat; and in like manner an additional quantity of eider-down in *water* encreaſed the difficulty with which it heated and cooled. For when pure water cooled 168° degrees in 597 ſeconds, water with $\frac{1}{50}$ of its bulk of eider-down diffuſed through it took 763 ſeconds, and with $\frac{1}{25}$ it required as much as 949 ſeconds. In all theſe caſes it was neceſſary to boil the eider-down with the water to detach the air that clings to it with great obſtinacy.

Fluids therefore acquire and loſe heat *principally* by the currents which always take place in them when partially heated, the warmer part aſcending, and of courſe the colder part taking a contrary direction: and whatever impedes theſe motions will, proportionally to the degree of impediment, hinder the tranſmiſſion of heat through the fluid.

This important and beautiful law is further illuſtrated by a moſt happy application made by Count Rumford, of a remarkable peculiarity that obtains in the ſpecific gravity of water at the lower temperatures. It was firſt noticed by Mr. De Luc, and afterwards examined more particularly by Dr. Blagden, that when water at a high temperature is cooled, its denſity encreaſes gradually (like all other bodies when loſing heat) to about the temperature of 40°, but, from this point to 32°, or as much below as it can be cooled without freezing, its denſity *actually diminiſhes*: ſo that juſt before it freezes it is conſiderably lighter than at 40°. No other fluid in nature is found to have this ſingular variation from the general law, and it is even wanting in ſtrong ſaline ſolutions. Further experiments have fully confirmed this diſcovery, but with ſome little modification as to the preciſe point of extreme denſity, the alteration being extremely ſmall for two or three degrees above and below 40°. Mr. Dalton[z] makes the maximum of denſity to be $42\frac{1}{2}$, and has added the curious fact that water expands equally at any equal number of degrees both above and below this point; ſo that the ſpecific gravity of water at 32°, which is $10\frac{1}{2}$° below the maximum of denſity, is the ſame as that of water at 53°, which is $10\frac{1}{2}$° above the maximum.

Count Rumford applies this principle in the following way.[a] When hot water is poured upon ice frozen to the bottom of a jar, the water on the ſurface of the ice immediately is reduced to 32°; but at this heat, being lighter than water a little warmer, it riſes into the hotter maſs above, whilſt water at or near 40° deſcends upon the ſurface of the ice. This again, by the further melting of a freſh portion of the ice is reduced to 32°, when it loſes part of its ſpecific gravity and riſes as the former

[z] Manch. Mem. vol. v. [a] Eſſays.

ſtratum did, ſending down at the ſame time a freſh portion cooled to about 40°. Thus, whatever be the heat of the water at top of the jar, the ice itſelf is only acted on by water at about 40°, for only at this denſity can it ſink through a ſtratum at 32°; and therefore, as long as an atom of ice remains unmelted, this aſcent of water at 32° and deſcent of water at 40° muſt take place.

Hence it is inferred that as much ice will be melted in a given time by ſuperincumbent water at 40°, as by the ſame quantity of boiling water when at reſt. In the experiment the undulation cauſed by the pouring in the water muſt have ſubſided before a fair compariſon can be made, and then it was actually found after allowing for accidental irregularities, that full as much ice was melted in equal times by the cold as by the hot water, however paradoxical it may appear at firſt ſight. Some powerful objections have been made to Count Rumford's opinion of the non-conducting power of water when at reſt, taken abſolutely; but there can be no doubt whatever that by far the greateſt part of the tranſmiſſion of caloric through fluids is made by the mutual currents of the hotter and colder part; and therefore that it is very ſlowly and with extreme difficulty that heat can be made to paſs downwards through fluids, the ſingle inſtance of water between 53° and 32° being excepted, which is only a confirmation of the fact.

Before we mention the objections to the opinion of the abſolute non-conducting power of water, we cannot reſiſt inſerting the beautiful ſuggeſtion attempted by the ſame ingenious philoſopher, of the final cauſe of this ſingular difference in the common law of regular condenſation by cold, which occurs in water and no other fluid in nature, and only when approaching to within a few degrees of the freezing point. The direct operation of this law is to retard congelation, and to preſerve a moderate temperature in all natural freſh waters during the ſevereſt cold, whereby it appears that the lives of a vaſt number of its ſubaqueous inhabitants are preſerved, and an opportunity is afforded to man and other animals to procure in the coldeſt ſeaſons this neceſſary element. The earth being always warmer in ſevere froſt than the air, the cooling of the waters on the face of the earth muſt of courſe begin from its upper ſurface, which is expoſed to the cold atmoſphere. Therefore, when an intenſe cold air ſweeps over a piece of water (a freſh-water lake for example) the ſurface as it cools becomes of courſe of greater denſity and ſinks down, giving place to the warmer ſtratum below to come to the ſurface. This in its turn becomes cooled and denſer, and again ſubſides to give room to the next ſtratum. Thus the whole maſs is firſt cooled to the point of extreme denſity, that is about 42°. But if this point were, like other fluids, the inſtant before freezing, the water would cool to 32° uniformly, after which (the external cold ſtill continuing much below that point) the next ſtep would probably be a ſudden congelation of the whole body of ice-cold water. But as the denſity of water diminiſhes from 42° to the freezing point, no further ſinking of the colder and riſe of the warmer ſtrata can take place, ſo that the upper ſtratum alone now receives the whole of the chilling action of the air, and there remains till it is converted into a cruſt of ice, the water beneath being all the while about 42°. When ice, it is ſtill a worſe conductor of heat than water at reſt, and thus it long interpoſes between the cold of the air and the warm water beneath, beſides that it protects it from the extreme chilling effect of ſweeping winds; and it muſt be very ſlowly, ſtratum after ſtratum, that the proceſs of congelation can proceed downwards through a conſiderable depth of water.

On the other hand the ſame circumſtance contributes to haſten the thawing of ice in a warm atmoſphere. If this peculiarity did not occur, and if water at reſt were an abſolute non-conductor of heat, it would be impoſſible that a maſs of ice ſhould ever thaw except by the ſlow and circuitous paſſage of heat upwards through the earth. For the firſt effect of the warm air would be to thaw a thin ſtratum on the ſurface of the ice, which if it were (as in other liquids) lighter than the cold ſurface that touched the ice, would only remain at reſt on the ſpot in which it was thawed, and would tranſmit no heat whatever to the ice below. Whereas, as it actually happens, the thawed ſurface with the firſt additional heat that it acquires, becomes *heavier* inſtead of lighter, and of courſe ſinks to the ſurface of the yet unthawed ice, imparts to it its exceſs of heat, and again, becoming lighter thereby, returns to the air, to acquire a freſh portion of heat which it again carries down. Thus a conſtant circulation of alternately warmer and colder water goes on above the ice till it is all thawed, and alſo proceeds further downwards till the temperature of the whole water riſes to about 42°; after which the uſual law of expanſion by heat is reſumed, for all the higher temperatures.

Experiments were alſo made by Count Rumford to determine whether heat could be propagated downwards through oil and mercury. Theſe fluids being uniformly dilated with any encreaſe of heat from any temperature at which they remain uncongealed, no ſuch precautions were neceſſary as when water near the freezing point was uſed. The apparatus uſed was a cake of ice frozen to the bottom of a jar, with a projecting point or nipple at the ſurface: this was entirely covered with the oil or the mercury, and a ſolid cylinder of iron heated in boiling water was let down through the oil or mercury to within $\frac{1}{10}$ of an inch of the nipple of ice. Though the heated iron was ſo near it, no ſenſible quantity of ice was melted; and as all the motions produced in the fluid by the unequal heating took place a little above the level of the ice, it ſhewed that the communication of heat through the fluids could only be made by means of heated currents, and therefore could not properly be *conducted* through them.

Though theſe very curious experiments ſhew inconteſtibly that the heating and cooling of fluids is *chiefly* carried on by means of the currents into which they are thrown when heat is partially communicated, there is very ſtrong evidence from ſubſequent experiments that this is not the only way in which caloric is propagated through them; or in other words, that fluids are not abſolute non-conductors of heat, though they are certainly very bad conductors.

The actual motion of the currents of differently heated particles in any maſs of fluid, has been attempted to be ſhewn in different methods. One of them, which was adopted by Count Rumford, is to ſuſpend in the fluid minute particles of any opake ſolid ſubſtance reduced to powder, which is not chemically acted on by the fluid, and whoſe ſpecific gravity is ſo nearly the ſame as that of the fluid in which it is immerſed that it will riſe or fall merely with the currents. Amber is a little heavier than pure water, but if a ſmall quantity of carbonat of potaſh or any other ſalt be added, it may eaſily be brought to the requiſite denſity, and no chemical action takes place between the two.

When a glaſs jar thus filled, and the fluid cold, is immerſed in another large jar containing very hot water, the particles of amber which before were at reſt in every part of the water, immediately begin to fall into regular currents, and all that are near the ſides of the jar, being the neareſt to the hot water on the outſide, begin inſtantly to *aſcend* with great rapidity and regularity, whilſt of courſe a *deſcending* current is formed in the centre of the jar. This continues, but with diminiſhing velocity, till the whole of the water in the inner jar is brought nearly to the ſame temperature, when the particles again remain at reſt. If the proceſs is reverſed, and the jar now hot is immerſed in *cold* water, or even ſimply expoſed to cold air, the currents now run exactly in a contrary direction, the outer circumference cooling firſt, and forming a *deſcending* ſtream, whilſt the inner cylinder of water of courſe *aſcends*; and theſe currents again continue till the temperature is equalized through the whole jar.

This moſt entertaining experiment, though it correſponds very well in *form* with what actually takes place in the water itſelf, differs eſſentially in *degree*; for the rapidity of the motion of the amber particles is much beyond what would be required to account for the actual rate of heating or cooling in the water itſelf. Therefore, much of the effect is owing to the expanſion or condenſation of the amber itſelf, rendering it lighter or heavier than the liquor in which it is immerſed; and theſe reſpective currents of the floating particles muſt be conſidered only as an imitation, or rather an exaggerated repreſentation of what actually takes place in the water. This was very ſatisfactorily proved by Dr. Thompſon,[b] who repeated the experiment nearly in the ſame way, but with the ingenious contrivance of colouring blue the lower half of the liquor, and leaving the upper part uncoloured. On applying heat at the bottom, the amber particles were readily ſet in motion, and they roſe not only to the top of the blue part, but through this into the colourleſs portion, *without being accompanied by any of the coloured ſolution*, which of courſe would have been readily viſible. By continuing the heat for ten minutes, the two liquors did indeed become uniformly mixed, but the motion of the amber particles began almoſt immediately on applying heat, and were fully eſtabliſhed through the whole of both liquors before the colour had ſpread upwards in any ſenſible degree.

Hence it follows, that the only ſatisfactory way of rendering the currents of the water itſelf viſible, is by tinging a part, and then the gradual admixture of colour can only be brought about by the actual admixture of the different particles of the fluid itſelf.

To prove the real conducting power of water,

[b] Ph. Jour. vol. i. 8vo.

or the paſſage of heat through it, unaccompanied by correſponding currents, very ſatisfactory experiments have been made by Dr. Thompſon,[c] Mr. Dalton,[d] and Mr. Murray.[e] All of them proceed on the general principle of endeavouring to communicate caloric in a direction contrary to that of the currents which are excited in partially heated fluids. In many of them a veſſel was filled with water unequally heated, in which, during the proceſs of cooling, no alteration of ſpecific gravity could make any current; and as notwithſtanding, the temperature of the water in the different parts of the veſſel gradually became equal, it was inferred that water (or whatever was the fluid uſed) poſſeſſed a real conducting power.

To fulfil theſe conditions, either a hot liquid muſt be put upon a ſtratum of the ſame liquid cold, or a hot liquid of greater ſpecific gravity muſt be put at the bottom, and a cold liquid of leſs gravity at the top. In either caſe there can be no current from one to the other. The particulars of theſe and other ſimilar experiments need not be related; in all there was a gradual equalization of the temperature, but not till a conſiderable time had elapſed.

Some nicety of management is required in pouring one liquor down a tall jar on the ſurface of another liquor without mixing the two in any material degree. To do it in the moſt expeditious and beſt way, a thin wooden float ſhould firſt be let down on the lower liquid and the ſtream of the upper liquid directed upon it, which will break the force of the current, and keep the two ſo much ſeparated, that if only one be coloured, the line of diſtinction will be obvious, and pretty well defined.

As caloric cannot radiate through denſe fluids, if it paſſes through them without the aſſiſtance of currents (that is, without being *conveyed*), it muſt be *conducted* through, unleſs it is communicated through the ſides of the veſſel that muſt be uſed to make the experiment. This has generally been of glaſs, which is itſelf a bad conductor of heat; but ſtill it cannot be denied that where one part of the ſame veſſel confines a hot and the other part a cold fluid, the varying quantities of heat abſorbed by the veſſel itſelf muſt after a time be equalized by the conducting power which ſolids indiſputably poſſeſs, and a conſequent equalization of temperature muſt ſooner or later take place in their contents by this cauſe alone, even were no other to operate. In thoſe of the above experiments that laſted many minutes, even as much as one or two hours, a very large deduction muſt be made for the conducting power of the veſſel, but a beautiful experiment of Mr. Murray's, made in a *veſſel of ice* (and therefore a perfect non-conductor for all temperatures above 32°, whilſt it continued to be ice), ſhews a conducting power in fluids independent of the veſſel containing them.[f] Some of the particulars may be mentioned. A quantity of water was frozen in a tin mould, ſo as to form a hollow cylinder 3 inches in diameter, $3\frac{1}{2}$ in depth, and of $1\frac{1}{2}$ thickneſs of ice. A thermometer was introduced into it horizontally, at the depth of one inch, the bulb being in the axis of the cylinder, and was frozen in. A quantity of almond oil was then poured into the ice veſſel, ſo as to cover the bulb of the thermometer one quarter of an inch. A ſmall flat-bottomed iron cup, holding two ounces by meaſure, was then ſuſpended over the oil, ſo as merely to touch the ſurface, without dipping to any ſenſible depth. This cup was then filled with boiling water; ſo that the heat paſſing through its bottom would directly touch only the ſurface of the oil, which was a quarter of an inch above the thermometer bulb. Thus ſituated, if the thermometer roſe, it ſhewed that the heat muſt have been fairly conducted downwards through this depth of the ice-cold oil, for the ſides of the veſſel being ice could not have conveyed it, nor would any heated currents reach ſenſibly lower than the bottom of the heated cup. The mercury roſe from 32° to $32\frac{3}{4}$ in a minute and a half, and to $37\frac{1}{2}$ in five minutes, after which it remained ſtationary for a while and then gradually ſunk again to 32°. The effect of the heat had excavated a portion of the top of the ice veſſel, and even as low as the bottom of the thermometer bulb. The ſame experiment was repeated, ſubſtituting mercury to the almond oil, and the iron cup was now allowed to float on the ſurface of the mercury, but ſtill at a ſenſible diſtance from the thermometer. This roſe inſtantly on the pouring the boiling water into the cup, from 32° to 36°, and again ſlowly ſunk to the freezing point.

Each of theſe experiments were repeated with different heights of fluid over the thermometer, and in all, ſome riſe of the thermometer was obſervable, though when covered with one inch of mercury it amounted to no more than three-fourths of a degree.

Having thus related the principal facts concerning the paſſage of heat through ſolids, liquids, and gaſſes, in its radiated and conducted ſtates,

[c] Ph. Jour. vol. 4. [d] Manch. Mem. vol. 4. [e] Ph. Jour. 8vo. vol. 1. [f] Ph. Jour.

before its chemical combinations are noticed, ſome further obſervations may be added concerning the expanſion, which invariably attends an encreaſe of the quantity of caloric in every ſubſtance in nature, in the circumſtances above mentioned.

Of Expanſion.

It is by the expanſion which fluids undergo when heated that the encreaſe or diminution in the quantity of ſenſible caloric in any body is uſually meaſured. This is done by the THERMOMETER. How far this inſtrument applies will be mentioned in the next ſection when treating of combined caloric.

The expanſion of ſeveral fluids has been meaſured with conſiderable accuracy, and the peculiarity that takes place in the expanſion of water at low temperatures has been noticed. This ſingular fact, firſt accurately aſcertained by Mr. De Luc, and afterwards by Dr. Blagden, has been further illuſtrated by Mr. Dalton,[f] who has ſhewn that water expands equally at equal degrees above or below its maximum of denſity. The experiments were made by filling a thermometer tube with water, and immerſing it in water of known temperatures, or in different freezing mixtures, uſing a good mercurial thermometer as a ſtandard. It has been mentioned that the maximum of denſity is ſomewhere about 40° to 43°, but the difference of expanſion for two or three degrees above or below 41°, is ſo ſmall as ſcarcely to be cognizable. Mr. Dalton eſtimates the maximum at $42\frac{1}{2}$, and finds that water incloſed in a thermometer bulb, may be cooled not only to about 21° (as Dr. Blagden had diſcovered) but even as low as 5° or 6° without freezing. When actually cooling below $42\frac{1}{2}$°, the water *riſes* on the ſcale, and exactly in correſpondence with equal diſtances above $42\frac{1}{2}$, ſo that for example when the liquor ſtands at 63° of the ſcale, it is impoſſible to tell by mere inſpection, whether it is actually 63° (20° *above* the maximum of denſity) or $22\frac{1}{2}$° (20° *below* the maximum).

A great difference takes place in the expanſion of different liquids by equal quantities of heat. This is not apparently connected with their ſpecific gravity, but as Dr. Thompſon[g] ſuggeſts it ſeems to depend on the degree at which the liquid boils, thoſe liquids having the greateſt expanſion whoſe boiling points are the loweſt. Thus mercury expands with a given temperature much leſs than water, whoſe boiling point is much lower; and water, again, expands leſs than alcohol, which boils at a lower temperature. So that as a general rule it may be laid down that the expanſibility of liquids is in ſome proportion inverſely as their boiling points.

Another important circumſtance concerning the expanſion of liquids is that they all expand more with equal additions of heat at the higher than the lower temperatures. This variation is not very uniform, nor is the law of the encreaſe in all caſes very obvious. In water, however, the encreaſe at the higher temperatures nearly correſponds with the ſquares of the natural numbers. Thus, if the original bulk of water be aſſumed as 10000, the expanſion at $82\frac{1}{2}$° may be taken at the ſquare of 6 or (36), and that of every ten degrees above $82.\frac{1}{2}$ will be ſucceſſively nearly as follows: at $92\frac{1}{2}$°$=7^2$ (49): at $102\frac{1}{2}$°$=8^2$ (64): at $112\frac{1}{2}$°$=9^2$ (81): and ſo on, according to the ſquares of the natural numbers. Owing to the peculiarity in the expanſion of water, juſt mentioned, the ſame rate of expanſion will alſo apply to the deſcending ſcale of heat, at like diſtances from $42\frac{1}{2}$°, as long as it can be preſerved unfrozen. M. De Luc has clearly pointed out how this encreaſing expanſion of fluids in the higher temperatures throws an unavoidable error on the common conſtruction of the thermometer, the ſcale of which always ſuppoſes equal expanſion, and of which the degrees divide equal ſpaces in the tube. Thus if, as is commonly done, two diſtant points of the ſcale are firſt marked (that of freezing and boiling water for example) and the ſcale is then divided into 180° equal ſpaces, it is obvious that 90° degrees from the freezing point, or half this ſpace, will not exactly indicate half the entire expanſion of the mercury from theſe two points, but the lower half of the ſcale will be too large, and the upper too ſmall. The real medium of temperature would be at 118.85° of the common ſcale, or 86.85 degrees above 32°, the freezing point.

By experiments on other fluids, M. De Luc found this difference to be greater, as will be ſeen by the following table. The ſcale of Reaumur's thermometer was uſed, which divides the interval between freezing and boiling water into 80 degrees. The mean number is therefore, by the ſcale, 40°, but the real mean of expanſion expreſſed in the firſt column is, in all the ſubſtances examined, lower than this point. The ſecond and third column of numbers expreſſes the proportion between the higher and lower parts of the ſcale of expanſion.

[f] Manch. Mem. vol. v. pt. 2.

[g] Elements of Chemiſtry.

Mercury - - - - -	38.6	15 : 14
Olive and linſeed oil -	37.8	15 : 13.4
Oil of camomile - -	37.2	15 : 13
Water ſaturated with ſalt	34.9	15 : 11.6
Alcohol - - - - - -	33.7	15 : 10.9

Mercury is however the moſt uniform in its expanſion for equal quantities of heat, of any fluid known, and doubtleſs chiefly for the reaſon already mentioned, namely, that its boiling point is higher than other fluids. Hence its peculiar advantage in the conſtruction of *thermometers*, under which article the expanſion of fluids will be further noticed.

The expanſion of ſolids is much leſs than that of fluids or gaſſes, and is ſo ſmall that it cannot be accurately obſerved without a micrometer, and mechanical contrivances of unequal levers for ſucceſſively multiplying the effect. Theſe machines are called *pyrometers*, and that invented by Mr. Smeaton is eſteemed one of the moſt perfect and accurate. A pyrometer of platina has been attempted by Guyton, [h] to meaſure the higher degrees of heat. It conſiſts of a bar of this metal encloſed in a groove of highly burnt clay, and with a complicated index at one end, whereby an expanſion amounting to not more than about a five-thouſandth of an inch is clearly aſcertained. The expanſion of ſolids appears to be pretty equable for equal quantities of heat.

Gaſſes and gaſiform vapors expand very largely by heat, much more ſo than ſolids or fluids. The dilatation of air is ſhewn very ſtrikingly by the *manometer* or *air thermometer* as it is ſometimes termed, which conſiſts ſimply in confining air in a bulb of glaſs by a column of coloured liquor that fills the tube communicating with it. On changing the temperature of the air in the bulb in any degree, however ſlight, the conſequent expanſion or contraction is immediately ſeen by a conſiderable fall or riſe of the coloured liquor. But as the extreme elaſticity of air cauſes it alſo to be enlarged or contracted by a diminiſhed or encreaſed preſſure of the atmoſphere, a barometrical correction on this account is always requiſite in manometrical experiments.

In all chemical experiments on which the quantity of gaſſes is to be eſtimated, the temperature at the time of meaſuring them muſt be taken into the account, and proper corrections made when this exceeds or falls ſhort of the ſtandard of compariſon. Thus 1000 parts of common air at 32°, expand to 1058 at 60°, and to 1104 at 82°.

A great number of experiments have been made by different perſons to aſcertain the expanſion of air by heat, as it is a ſubject intimately connected with many phyſical obſervations, and in particular with all barometrical experiments. When the natural atmoſphere is examined, the quantity of water which it holds in ſolution moſt eſſentially modifies the expanſibility, and in low temperatures much of the aqueous vapour which it held in ſolution is deſtroyed and ſeparated in a liquid form. This vapour may be almoſt entirely ſeparated from air by ſeveral chemical means, ſuch as putting the air in contact with ſulphuric acid, or ſolid potaſh, which have ſo ſtrong an affinity with water as to extract it from the air that holds it in ſolution.

From late experiments by Mr. Dalton in England, and M. Gay Luſſac in France, both of which bear the mark of great accuracy, and correſpond very cloſely with each other, the very important and convenient inference is deduced, that all gaſſes expand equally by equal degrees of heat, provided they be free from condenſable vapour at the temperatures at which the experiments are made. Hence a table of the expanſion of any one gas will apply to all the reſt.

Gaſſes alſo appear to expand pretty equally for equal degrees of heat, and not in an encreaſing ratio, like water or other denſe fluids. Indeed the thermometer indicates a contrary rate of expanſion, that is, one that regularly diminiſhes as the temperature encreaſes; but Mr. Dalton very acutely ſuggeſts that this anomaly is in all probability only owing to the inaccuracy of the thermometer itſelf, which from its being divided into equal degrees, is not a perfectly accurate meaſure of equal expanſions in the higher temperatures, for the reaſon already mentioned: and the effect of the inaccuracy in this inſtrument is to give to a really equal expanſion the appearance of a diminiſhing ratio. The experiments on the expanſion of aeriform bodies will be given under the article Gas.

The only apparent exceptions to the general law of the expanſion of all bodies by heat are, the regular contraction of baked clay in encreaſing degrees of heat, on the one hand, and on the other the great expanſion which many liquids undergo in the act of congelation. With regard to the former it will be further explained under the article Pyrometer *(Wedgewood's.)*

The degree of expanſion which water undergoes by congelation is very conſiderable, and its force is one of the moſt (if not the moſt)

[h] An. Chim. tom. 46.

prodigious of any of the ſpontaneous actions of natural bodies. If a block of ice ſwimming in water may be eſtimated to riſe about one-ſixth of its bulk above the ſurface of the water, five parts of water by weight would occupy about the ſame bulk as ſix of ice. The force of expanſion was long known to be ſuch as to burſt any veſſel in which water was ſet to freeze, if filled full; and by Major Williams's experiments at Quebec, this force was found in intenſe cold to be able to burſt very large pieces of ordnance. For the particulars of theſe, ſee the article FREEZING.

Some of the metals expand on their congelation or fixation. Iron is of this kind, and hence the unmelted metal will ſwim on the ſurface of the melted; whereas ſilver, lead, and many others, contract on cooling, and therefore ſink in a melted maſs of the ſame metal. The chief cauſe of this expanſion in water, metal, and in an infinite number of ſaline and other ſolutions, when paſſing from the fluid to the ſolid ſtate, appears without doubt to depend on the new arrangement of particles produced by the *cryſtallization*, but the ſubject is ſtill very obſcure. However it does not in the leaſt invalidate the general law of expanſion by heat, ſince theſe ſame ſubſtances when ſolid are expanded and contracted as before by gain or loſs of caloric.

OF COMBINED OR LATENT CALORIC.

In the two preceding ſections of radiated and conducted caloric, heat has been conſidered only in that ſtate of freedom or of looſe combination in which it exiſts in its paſſage through ſolids, fluids, and gaſſes. This is properly the *caloric of temperature*, or that whereby the equilibrium of temperature is conſtantly kept up in all bodies in nature; and, as has been amply ſhewn, no ſubſtance, whatever difficulty caloric finds in permeating it, can abſolutely detain it or prevent its paſſage. Perhaps the term of *tenſion* of caloric, adopted by Prevoſt, Pictet, and ſome other writers, will expreſs with more exactneſs the idea which may be formed of this ſtate of caloric. This is meaſured by the thermometer, that is by a very ſmall maſs of matter (generally mercury) extremely permeable by heat, which, when put in contact with the ſubſtance examined, readily acquires the ſame tenſion of heat, without leſſening the actual quantity in any ſenſible proportion by what it abſorbs, and furniſhes a comparative ſcale of temperature by the expanſion which it undergoes. That the thermometer does not meaſure the actual quantity of caloric is evident from the circumſtance that it gives the ſame indication immerſed in a large as in a ſmall maſs of matter. Thus it is obvious that two pounds of boiling water contain twice as much caloric as one pound of boiling water, but the thermometer in both ſtands at the ſame degree. Neither does this inſtrument give the comparative quantities of caloric in the ſame bulk of different ſubſtances. If ſeparate veſſels containing water, mercury, oil, brine, &c. are all immerſed in water kept a ſufficient time at the boiling point, after a greater or leſs time they will all acquire a temperature a few degrees below 212°; but this does not in the leaſt prove that they contain equal quantities of heat, and the circumſtance of the unequal times required in each to arrive at this point is a ſtrong argument againſt the quantities of caloric being equal.

The analogy given by M. Pictet between humectation and heating, will further illuſtrate, as far as it holds, the nature of thermometrical indication. Suppoſe at the ſame inſtant a pound of dried ſponge, a pound of blotting paper, and a pound of ſome porous wood be plunged into a baſon of water. After a ſhort time the ſubſtance that receives water the eaſieſt (ſuppoſe the blotting paper) will be thoroughly ſoaked; in a little longer time the ſponge will be in the ſame condition, and after a longer time, the wood. When taken out of the water they will all be thoroughly wet, and if a hygrometer (which is a machine that ſhews the degree of moiſture of the air by expanſion or contraction of hair, catgut, or any other hygrometrical ſubſtance) could be applied to them all, it would only ſhew in each the ſame and the extreme degree of humidity, but would give no indication whatever of the actual quantity of water which each contained. In this therefore it reſembles the thermometer applied to heated bodies. Let the three ſubſtances be now thoroughly dried in a very warm ſituation, and the hygrometer would only mark in them the term of extreme dryneſs, and not the quantities of water which they had reſpectively loſt, which would be the moſt in the ſponge, the next in the paper, and the leaſt in the wood. But after this thorough exſiccation, if the three ſubſtances were ſtrongly heated in cloſe veſſels, they would yield a further quantity of water, alſo in unequal proportions, as the wood would now furniſh the greateſt; and this may bear an analogy to the caloric of combination, which is no more indicated by the thermometer than the combined water would be by the hygrometer.

Let a quantity of ice cooled down to 20° be put in a veſſel and gently heated by a ſmall

lamp that burns ſteadily and equally. If a thermometer be immerſed in the ice it will gradually riſe from 20° to 32°. The ice will now melt ſlowly, and during the whole time of melting, the thermometer touching it will remain ſtationary, notwithſtanding the acceſſion of heat continues as before. Therefore, during the melting of ice, a quantity of heat inſenſible to the thermometer is abſorbed; and if the heat is communicated from the bottom, the water already produced is prevented from acquiring a higher temperature till every particle of the ice is thawed. Hence it follows that a quantity of heat is neceſſary to be added to ice before it can be converted into water, and which does not raiſe the thermometric temperature. Let the heating continue as before, and the water produced by the thawing of the ice now again ſhews an encreaſe of ſenſible heat, and the thermometer continues to riſe gradually through the whole ſcale up to 212°, in the latter part of which time the water begins to ſend forth ſteam, and at laſt to boil violently. Now again a ſecond and permanent ſtop is put to the riſe of the thermometer, for though the addition of heat received from the lamp continues as before, the thermometer never riſes higher than 212°, but inſtead, a large quantity of aqueous vapour flies off, alſo at the heat of 212°, till every drop of the water is evaporated. Now if in the firſt caſe all the heat received during the thawing of the ice (at which time the thermometer was ſtationary) was abſorbed by the water in order to enable it to aſſume the liquid form, it follows, by parity of reaſoning, that all the heat received during the boiling (the thermometer being now as before ſtationary) is employed in the converſion of water into aqueous vapour. In both caſes heat is received, and as it is the common effect of heat to raiſe the thermometric temperature, the abſence of this effect can only be accounted for by ſuppoſing it neceſſary for the exiſtence of aqueous vapour that it ſhould be compoſed of a greater quantity of heat than water, and water more than ice.

Upon theſe fundamental experiments, Dr. Black formed that beautiful ſyſtem of the nature of heat which carried with it irreſiſtible conviction wherever it ſpread, which is now (with ſome modifications) univerſally adopted, and has been extended to the full explanation of an infinite number of the moſt important phenomena in natural philoſophy. The particular experiments and inferences from them muſt be examined more minutely. The leading circumſtances or heads of inquiry ſuggeſted and illuſtrated by Dr. Black's diſcovery, are the following:

1. The abſorption of caloric from the ſurrounding bodies by liquids in the proceſs of liquefaction, and by vapours in the proceſs of evaporation, being neceſſary to the conſtitution of liquids and vapours. Caloric in this ſtate is termed by Dr. Black *Latent Heat*, becauſe it is as it were concealed in the ſubſtance of the liquid or vapour; and is oppoſed to *Free or Senſible Heat*. Latent heat has been alſo termed *Combined* caloric, which is perhaps a better term, as it expreſſes (what is probably the fact) that a chemical combination takes place; as (for example) between ice and caloric to conſtitute the fluid, water.

2. The expulſion of caloric from liquids during congelation, and from vapours during their condenſation into liquids. In this caſe the caloric which was before in a latent ſtate now becomes free, and therefore ſenſible to the thermometer. This expulſion of caloric is of courſe a neceſſary inference from the fact of its abſorption in oppoſite circumſtances, and the proofs of its taking place are equally decided.

3. The proportional quantity of caloric neceſſary to be added to any ſubſtance to raiſe it to a given thermometrical temperature. This compariſon refers both to the different ſtates of the ſame body (as ice, water, and vapour) or to different bodies indiſcriminately, the quantities of the ſubſtances being always equal. As theſe experiments are proportional to each other, they are for convenience all referred to a common ſtandard, which in this caſe, as in that of ſpecific gravities, is water. This is called the *Specific Caloric* of bodies, or as Dr. Black terms it, the *Capacity of Bodies for Heat*. Thus if it takes three times as much heat to raiſe a certain quantity of water 10 degrees, as the ſame quantity of mercury, the ſpecific caloric of water, or its capacity for heat, is ſaid to be three times as great: or if that of water be called 1. that of mercury will be $\frac{1}{3}$.

4. The abſolute quantity of caloric contained in any ſubſtance. We have no reaſon to think that we have ever by natural or artificial cold deprived any ſubſtance of all the caloric which it contains; but many ingenious attempts have been made to eſtimate the point of actual privation of heat, or the real zero in different bodies, and thence to compute the abſolute quantity which is contained in ſubſtances at given temperatures. As heat cannot be weighed or meaſured, ſome meaſure of effect muſt be

adopted to expreſs abſolute quantities of it. This has been done either by the thermometer, or by the thawing of a given weight of ice.

Of Liquefaction and Congelation.

The oppoſite ſtates of *Liquefaction* and *Congelation* may be conveniently deſcribed under the ſame head, as the circumſtances attending the one will illuſtrate the other, after which the ſimilarly contraſted phenomena of evaporation and condenſation of vapour will be noticed.

During the liquefaction of any ſubſtance by mere heat, it has been already mentioned that a large quantity of heat is abſorbed by the melting ſubſtance which is eſſential to the conſtitution of the ſtate of liquidity, and does not raiſe the thermometrical temperature. Conſequently if a ſolid ſubſtance, cold, and the ſame ſubſtance in a liquid ſtate, and hot, be mixed in known proportions, the temperature after mixture will not be the proportional mean of the temperature of each, as would be the caſe if both were liquid, but will fall far ſhort of it: a great portion of the heat of the hotter body being taken up with melting the colder ſolid body before its temperature can be raiſed a ſingle degree. Thus, equal parts of water at 32°, and water at 212°, will on mixture give the temperature of 122°, or the arithmetical mean between theſe two numbers; but equal parts of *ice* at 32° and water at 212°, will give only a temperature of about 52°, the greater portion of the heat of the water being firſt employed in thawing the ice before any riſe of temperature whatever can take place in the mixture.

Dr. Black's original experiments[1] on the abſorption of heat during the proceſs of liquefaction may here be ſhortly mentioned, on account of their elegant ſimplicity, as they ſerved as ground-works of his beautiful ſyſtem.

Two equal globular glaſs veſſels were filled, the one with five ounces of water, which was afterwards frozen by ſurrounding it with ſalt and ſnow, and the other with water ſimply cooled down to 33°. That which contained the ice was allowed to remain in a warmer air till the ice juſt began to melt, at which time its temperature was as nearly as poſſible 32° or 33°. The two veſſels were then ſimply ſuſpended from a wire frame ſet in the middle of a large room without a fire or any notable draught of air, and of the average temperature of 47°. The veſſels were therefore in every reſpect under ſimilar circumſtances of temperature within and without, and with ſimilar contents, excepting that one contained ice and the other water. The progreſs of heating was then noted. In that which held the water the thermometer roſe in half an hour to 40°; but in the other it took no leſs than 10 hours and a half before all the ice was melted, and the contents had reached to 40°. Conſequently the rate of heating was 21 times ſlower in the ice-veſſel than in that which held the cold water; but the actual heat received by the former was nearly uniform the whole time, and therefore it required about 21 times as much heat to bring ice to the ſtate of water and to raiſe it to 40°, as to raiſe ice-cold water to the ſame point. Or, to expreſs it by another form, if the water had continued to receive as great an influx of heat as the ice, during the whole 21 half-hours, its temperature would of courſe have been raiſed 21 times as much as during the ſingle half-hour, and as this was 7 degrees, the whole would have been $21 \times 7 = 147$ degrees. The difference between the gain of temperature in the ice and the water with equal acceſſions of heat, is about 140 degrees; and therefore 140° is the expreſſion of that quantity of thermometric temperature which is deſtroyed, or made *latent*, by the ſeparate operation of the liquefaction of ice, the actual quantities of matter in the compariſon being equal.

This calculation was confirmed by the experiment of melting ice in hot water, and comparing the temperature of the mixture with what it would have been had ice-cold water been uſed inſtead of ice. When quantities of water of unequal temperature are mixed together, the heat of the mixture is the exact mean of the difference of temperatures and the reſpective quantities. In Dr. Black's experiment, 119 parts of ice at 32° were melted by 135 parts of water at 190°, to which muſt be added the heat communicated by the hot veſſel, which he eſtimated as equal to 8 more of the water, making in the whole 143 parts. Now the gain of temperature produced by adding 119 parts of *water* at 32°, to 143 parts of water at 190°, would have been 86 degrees above 32°, or 118° of the ſcale; (being found by multiplying the difference of temperature into the weight of the hotter water, and dividing by the ſum of the weights of both, for $\frac{158 \times 143}{262} = 86$). But the temperature reſulting from the melted *ice*, and hot water was only 21 degrees above 32, or 53° of the ſcale. Therefore a quantity of heat had diſappeared, which would have raiſed the whole maſs (equivalent to 262 parts of water) 65 degrees, being the difference

[1] Lectures on the Elements of Chemiſtry.

between 86° and 21°. But the ſame quantity of caloric which would raiſe 262 parts of water 65 degrees, would raiſe 119 parts 143 degrees; and the weight of the ice alone being 119, it follows that during its liquefaction, heat is abſorbed equivalent to 143 degrees of temperature, and which can in no other way be accounted for than by ſuppoſing it intimately combined with the water as it becomes liquid, and eſſential to its ſtate of liquidity.

The near correſpondence of this experiment with the former, the one giving 140 and the other 143 degrees, is a convincing proof of the truth of the general inference drawn from them; for this does not depend on minute obſervation where an inaccuracy of a degree or two or any inequality of mixture will defeat the object of the experiment, but upon a large, palpable, and ſtriking difference which muſt be obvious to every obſerver.

To ſave the trouble of any calculation of proportion, this beautiful experiment may be made with equal or with aliquot weights of ice and hot water. So if a lump of ice is dropped into an equal weight of water heated to 200°, 140 degrees of heat may be firſt ſubſtracted from the hot water to counterbalance the liquefaction of the ice, and the real effect will therefore be the ſame as if water at 60° and ice-cold water at 32° were mixed in equal proportions, and accordingly the heat of the mixture will be the mean of 32° and 60°, or 46°. If the hot water be twice the weight of the ice, only half the quantity (or 70 degrees) muſt be ſubſtracted, and ſo in proportion.

The general law deduced from theſe experiments, therefore, is that *liquefaction* always demands the addition of a great quantity of caloric beyond what the thermometer will indicate, and hence a ſubſtance during this change abſorbs caloric powerfully from all the ſurrounding bodies, and leaves them *comparatively cold*. Liquefaction is therefore a frigorific proceſs, and this diſcovery explains the production of cold and the theory of freezing mixtures in a great variety of inſtances. Many of theſe will be mentioned after the oppoſite proceſs of congelation has been deſcribed. Liquefaction at the higher temperatures is often termed *fuſion*, thus we rather ſay the *fuſion* than the *liquefaction* of metals, or even of wax, ſpermaceti, &c. But in all theſe caſes an abſorption of caloric alſo takes place, which is ſhewn by preventing the ſubſtances from acquiring a higher temperature than their point of fuſion, as long as a particle remains unmelted; or by reducing the temperature of the melted ſubſtance immediately to this point, when above it, if a piece of the unmelted body is thrown in. Thus a ladle full of lead cannot be heated red-hot till all the metal is melted; and a quantity of red-hot melted lead is directly cooled to the point of fuſion by the addition of ſolid lead.

Since caloric is *abſorbed* during liquefaction, it follows that it muſt be *given out* during congelation; or, that not only the free thermometrical heat will be lowered to the congealing point, but that the latent caloric combined with the liquid will alſo be expelled before congelation can take place. Similar experiments to ſome of thoſe already deſcribed, will therefore apply (changing the circumſtances) to the phenomena of congelation. Thus if a veſſel of warm water is expoſed to a very cold medium, the temperature is rapidly cooled down to the freezing point, after which the water begins to congeal. If kept in the ſame ſituation, caloric is abſtracted as before, but the thermometrical heat now remains nearly the ſame, till all the water has loſt its whole ſtock of combined caloric neceſſary to fluidity, and is totally converted into ice, and it is not till after this period that the temperature begins again to ſink as before. Alſo if ice, however cold (ſuppoſe at 0°) be added to water at 32°, the effect is to congeal a portion of water, and the caloric given out by the water in the proceſs raiſes the temperature of the ice to 32°. Therefore ice ſwimming in water can never have a lower temperature than 32°, and this point is ſo invariable as to furniſh an excellent ſtandard for the graduation of thermometers.

Congelation therefore is as much a *heating* proceſs to the ſurrounding bodies, as liquefaction was ſhewn to be a *cooling* proceſs. That is, the reduction of the temperature of any ſubſtance to any given point below its freezing point is much retarded, if in the proceſs it be neceſſary to convert a liquid body into a ſolid by the abſtraction of caloric: for ice at 32° can much ſooner be cooled 10 degrees, than water at 32°, the ice having only to ſurrender its free uncombined caloric, but the water having, in addition to this, to give up its latent caloric of fluidity.

The heating power of congelation with reſpect to the ſurrounding bodies, is generally to be ſhewn only by its retarding the rate of the cooling which theſe bodies would experience without the influence of this proceſs. In a few inſtances however it is more ſtrikingly ſhewn by an actual *riſe* of a thermometer immerſed in fluids at the moment of their congelation. The

following experiment of Fahrenheit ſhews it. If water (and better juſt after having boiled for a quarter of an hour) be put into a deep veſſel immerſed in ſalt and ſnow, or any other powerful freezing mixture, and allowed to remain perfectly at reſt and without any wind playing over its ſurface, it may readily be cooled to about 8 or 10 degrees below 32°, or even more without freezing. If now the veſſel be ſlightly ſhaken or jarred, or eſpecially if an atom of ice be dropped in, almoſt the whole water ſuddenly ſhoots into fine cryſtals of ice, and the temperature ſlowly *riſes* to 32°, the freezing point. The reaſon of this conſiderable riſe of the actual temperature is the ſuddenneſs of the congelation. In common circumſtances the formation of ice in freezing water is ſo gradual, that the latent heat extricated from the water by congelation is immediately diffuſed through the ſurrounding medium, and does not ſenſibly affect the thermometer: but when the whole is cooled ſo low as 20° or 22°, the whole of the latent heat is ready to quit the water at the inſtant that congelation begins in any one point, and then becomes ſenſible to the thermometer.

The cryſtallization of thoſe ſalts that are more ſoluble in hot than in cold water is a true congelation, and the extrication of caloric from them in the moment of cryſtallization equally takes place. None of them ſhews this phenomenon more beautifully than ſulphat of ſoda (Glauber's ſalt); but ſome little management is requiſite to enſure its cooling down below its congealing point, and remaining fluid. The following method ſeldom fails. Take any quantity of this ſalt, a pound for example, and heat it in a clean iron ladle on a clear briſk fire. The ſalt ſpeedily melts in its own water of cryſtallization, and boils violently. Continue the heat till all the water is expelled, and a white dry ſaline maſs remains. Then add ſufficient water to it (without removing it from the ladle) to rediſſolve by boiling almoſt, but not quite, the whole of the ſalt. This liquor, which is a perfectly ſaturated ſolution, ſhould be poured, while ſtill quite hot, into a thin glaſs phial, and immediately corked quite cloſe, or better, covered with wet bladder, ſo as to exclude all the external air from the ſolution. Set this by in a quiet place without ſhaking, and it will now cool to the temperature of the air, remaining perfectly fluid. On opening the cork and letting in the external air, the liquor immediately begins to congeal on its upper ſurface, and the congelation ſpreads downwards in a few ſeconds, like a denſe white cloud; after which it is ſo entirely ſolidified that on inverting the bottle not a drop of liquor falls out. If it ſhould not immediately congeal on opening the cork, a ſlight ſhake, or dropping in an atom of the ſame ſalt will begin the proceſs, after which it never fails to ſpread through the whole in a few ſeconds. It may be added that the ſame ſolution will anſwer repeatedly any number of times, and after the firſt time there is no occaſion previouſly to calcine the ſalt, but merely to heat the phial containing it till it is totally liquefied. During the ſudden congelation, a quantity of heat is given out ſufficient to make the outſide of the phial ſenſibly warm to the hands, and to raiſe the thermometer 20 or 25 degrees. The cauſe of this encreaſe of temperature can be no other than the eſcape of the latent heat of the ſolution cauſed by its change from a fluid to a ſolid ſtate.

Numberleſs facts might be adduced in illuſtration of what has been mentioned concerning the evolution of ſenſible heat during congelation, and its abſorption during liquefaction. As a general rule it may be remarked that whatever melts the moſt rapidly is likely to produce the greateſt cold, and whatever congeals the moſt rapidly will *(ceteris paribus)* produce the moſt heat. However this is alſo regulated by the relative affinity for caloric which different ſubſtances may have. The mode in which artificial cold is produced by ſaline ſolutions partly belongs to this part of the ſubject.

In all theſe caſes a ſudden liquefaction of the ſalt employed takes place, which therefore requires a proportional ſupply of caloric from all the adjacent bodies to furniſh it. Thus if ſalt and ſnow (one of the moſt powerful of the freezing compounds) are mixed together, they melt with great rapidity (the ſnow ſimply by the abſorption of heat, the ſalt by the united power of caloric and water), and every ſubſtance immerſed in the mixture is robbed of a large portion of its caloric to ſupply the demand. The quantity of heat abſorbed, or the meaſure of the frigorific power, always bears a proportion to the cold required to congeal the mixture. Thus the freezing point of the brine is at leaſt 32 degrees lower than that of water, or the zero of the common ſcale, and hence we may infer that a much larger quantity of latent caloric is contained in brine than in water at equal temperatures, ſince ſo much more powerful a cold is required to congeal the former than the latter. The utmoſt limit of the frigorific power of theſe mixtures, therefore, is their point of congelation; for the ſame reaſon that prevents melting

ice from producing a greater cold than 32° during its liquefaction, will prevent brine from producing a lower temperature than about 0°, theſe being reſpectively the freezing points of the two ſubſtances. In like manner the cold occaſioned by ſalt and ſnow continues nearly at the ſame intenſity during the whole time of melting; as alſo takes place with melting ice: and if brine be ſlowly cooled a few degrees below 0°, its freezing point, as ſoon as any portion of the ſalt ſeparates in a ſolid form, the temperature *riſes* to that point; juſt as the temperature of over-cooled water riſes to 32° on ſudden congelation. [k]

The particular freezing mixtures, with the beſt mode of their application, will be deſcribed under the article FREEZING.

Of Vapour and Evaporation.

When water is heated in any open veſſel, the thermometrical temperature riſes gradually, at the ſame time that aqueous vapour ſoon begins viſibly to form at the ſurface. This encreaſes till the water has riſen to its boiling point, which is about 212° of the common thermometer; at which time the whole is thrown into violent agitation, and the formation of ſteam is rapid and copious. The temperature now no longer riſes, but remains, both in the water and in the ſteam, at the ſame point, till the whole is evaporated or boiled away.

The two principal circumſtances to be attended to in this proceſs, which is every day before our eyes, are, the expanſion which the water undergoes by being converted into ſteam; and the uniformity of temperature maintained notwithſtanding the conſtant acceſſion of heat during the boiling.

The invariable relation between the quantity of heated vapour formed, and the quantity of heat carried off in a ſtate inſenſible to the thermometer, led Dr. Black to apply his beautiful theory of latent heat to the vaporization of liquids as well as the liquefaction of ſolids, and has furniſhed the moſt irrefragable arguments for its truth.

The expanſion of water when converted into ſteam was long known to be very great, and many experiments were made, before Dr. Black's inquiries, to aſcertain the exact amount. More accurate trials, by Dr. Black, and his eminent pupil and friend, Mr. James Watt, fix the expanſion at 1800 times the bulk of the water. As vapour, while ſuch, is a rare, inviſible and highly elaſtic fluid, the temperature and preſſure muſt be taken into account in this eſtimate. The former is 212°, or the higheſt heat that unconfined watery vapour can aſſume, and the latter is the common preſſure of the atmoſphere. Hence we may reckon generally that water kept fully boiling in open veſſels is converted into 1800 times its bulk of boiling-hot vapour.

The combination of a great quantity of caloric with water in the formation of ſteam, was determined by Dr. Black in a ſimilar manner as the combination of caloric with ice, in order to produce liquefaction. Water was heated as uniformly as poſſible in a tin veſſel to boiling, and the time required for this was noted. The ſame heat was then continued till the whole was evaporated, and the time taken up by the proceſs was noted. Now ſince on the one hand the acceſſion of heat was conſtant, it was readily computed how high the temperature would have been, ſuppoſing the riſe to have gone on above 212° in the ſame ratio as below it; and, on the other, as the temperature of the ſteam was not raiſed, it was inferred that all the acceſſion of caloric from 212° was eſſential to the very ſtate and conſtitution of vapour at that temperature. This quantity Dr. Black eſtimates from the average of many of his firſt experiments to be about 810 degrees: that is to ſay, that the ſame quantity of caloric which is required totally to evaporate boiling water at 212°, would be ſufficient to raiſe the water 810 degrees above the boiling point, or to 1022 if it had remained in its liquid ſtate.

On the other hand, it will follow that when ſteam is condenſed again into water, it will give out all the latent caloric which was neceſſary to its vaporous ſtate, which being now ſet free from its combination, will readily be diffuſed among all the adjacent bodies, and raiſe their temperature as much more than an equal weight of boiling water will do, as the latent caloric of ſteam exceeds that of water. This furniſhes another method of eſtimating the latent caloric of watery vapour, and ſomewhat more accurate than the former, ſince in the experiment of boiling water ſome of it evaporates before it arrives at 212°, and it is neceſſary to aſſume as a datum that the rate of thermometrical heat in this fluid would be the ſame above the boiling point (were there no evaporation) as below it.

The moſt convenient method of heating water by means of ſteam, is to imitate the proceſs of common diſtillation; that is, to heat water in a cloſe veſſel in order to generate the aqueous vapour, and to cauſe the vapour to be condenſed in a metallic pipe paſſing in a ſpiral form through

[k] Black.

a tub, or any other veſſel that contains the cold water, which is to receive the heat given out by the ſteam during its condenſation. Here the vapour does not indeed actually come in contact with the water, but its latent caloric is given out and paſſes through the metallic pipe immerſed in the water. In perfect accuracy the quantity of caloric required to raiſe the temperature of the metallic pipe ſhould alſo be eſtimated, but here (as in the experiments on congelation) this minuteneſs of obſervation is not in the leaſt neceſſary to eſtabliſh the general law of latent caloric, the thermometrical difference on which it is founded being ſo great and palpable that very conſiderable errors are not felt. The experiments of Dr. Black and of Mr. Watt on the condenſation of a given weight of ſteam in a known quantity of water, give about 950° for the latent heat of ſteam or aqueous vapour at the boiling point: that is to ſay, that boiling water renders latent during its total converſion into ſteam a quantity of caloric, which otherwiſe would have raiſed it to 950 degrees. This enormous quantity of heat given out by ſteam was long obſerved during the common proceſs of diſtillation, and remained unaccounted for till the theory of latent heat occurred to Dr. Black. Of late the uſe of ſteam has been moſt advantageouſly extended to the heating of large maſſes of water in breweries, dye-houſes, bleacheries, &c. In theſe the ſteam is produced in a ſtrong iron boiler, with no other outlet than the pipe or pipes which convey off the ſteam when generated. One pipe paſſes to each ciſtern of cold water, and heats it, not as in diſtillation by merely paſſing through, but by diſcharging the ſteam into the body of the water, being generally admitted from below. A few minutes of a ſtrong jet of ſteam will bring a large ciſtern of cold water to a ſcalding heat, and a further quantity will ſoon raiſe it to boiling.

The facts that have been advanced concerning the latent heat of ſteam (and the ſame applies to all condenſible vapours) are finely illuſtrated by the inſtrument called from the inventor *Papin's* digeſter. Its intention is forcibly to confine heated water by mechanical preſſure, and thus to prevent the formation of ſteam, whereby the water is compelled to aſſume a much higher temperature than 212°. It conſiſts merely of a very ſtrong iron or copper boiler, whoſe lid fits on perfectly tight, and is kept down by thick ſcrews. This is half filled with water, the lid cloſed, and ſet on a fire. The water ſoon riſes to the boiling point, and ſo much ſteam is formed as will fill the vacant ſpace above. By continuing the heat, the water being prevented by the confinement from forming more than a limited quantity of ſteam, now rapidly acquires a much greater heat than 212°, and by this is enabled to diſſolve bone, horn, muſcle, and a great many other ſubſtances on which unconfined boiling water has but very trifling action. To prevent the great hazard of a dangerous exploſion from the prodigiouſly accumulating expanſive force of the ſteam within, the digeſter is furniſhed with a very tight valve, kept down by a conſiderable preſſure, but which will fly open before the veſſel is in any danger of burſting. The circumſtance that ſtrongly illuſtrates the theory of latent heat is the following. When the water within the digeſter has riſen to an exceſſive heat (ſuppoſe 400°, which is 188 degrees above the natural boiling point) if the valve is now opened, a quantity of ſteam ruſhes out with extreme violence, and the heat of the remaining water within almoſt immediately ſinks to about 212°. Thus we find that the formation of a certain quantity of ſteam from over-heated water, carries off with it a great proportion of the ſenſible heat of the water, and both ſteam and water fall to a much lower temperature than before, which can only be explained ſatisfactorily by the hypotheſis of the large proportion of heat rendered latent in the ſteam at the moment of its formation.

The converſion of water into aqueous vapour is therefore a *cooling* proceſs with regard to all the contiguous bodies, for the ſame reaſon that the liquefaction of ice or other ſolid bodies produces the ſame effect: and on the contrary, the condenſation of a vapor into a liquid, and of a liquid into a ſolid, are for the ſame reaſon *heating* proceſſes. This general law applies not only to water, but to all known ſubſtances whoſe form alters by different doſes of caloric.

The cold produced by the evaporation of fluids at low temperatures furniſhes many intereſting and very illuſtrative experiments. Alcohol and ether are fluids that boil at a much lower temperature than water, and they, as well as water and many other fluids, readily evaporate at a much lower heat than their boiling point, even at the common heat of the atmoſphere, and thus any ſubſtance moiſtened with any evaporable fluid is rendered much colder, or is robbed of much caloric, by the ſpontaneous evaporation of the fluid. This is much aſſiſted by a briſk wind, or any artificial renewal of the air on the moiſtened ſurface. Thus if a wet

cloth is ſpread out in a keen wind at a temperature a little above freezing, the water by rapidly evaporating ſoon cools the damp cloth below the freezing point, and makes it hard and ſtiff with the formation of ice within its pores. But the cold produced by evaporating ether is ſtill more ſtriking. A little of this ſingularly evaporable fluid poured on the back of the hand flies off immediately, and leaves the hand exceſſively cold. If a thermometer bulb is kept conſtantly damp with ether, the mercury ſinks rapidly many degrees below 32°, and if the evaporation is aſſiſted by agitation, or by a very ſtrong draught of air, the mercury may be lowered to a much greater cold than any natural to this climate, except in very rare inſtances. This is readily performed in a few minutes with a ſmall delicate mercurial thermometer: if the bulb be wrapped round with a little tow, ſoaked by once dipping it in ether, and blown upon with a hand bellows held a little diſtance off, it will then ſink as low as 0°, or even a degree or two lower.

The evaporation of all fluids is regulated as much by the denſity of the air with which they are in contact as by the degree in which they are heated, and in a direct ratio to each other; ſo that the denſer the atmoſphere preſſing on them, and the higher is the evaporable or the boiling heat required. Hence it follows that by diminiſhing the preſſure, liquids will boil at a much lower temperature than their natural point of ebullition. Thus it is found that at the top of high mountains liquids boil much ſooner than at the bottom. Sauſſure found that water boiled at the top of Mont Blanc at 187° Fahr. inſtead of 212°, and other liquids in proportion. The ſame effect is produced artificially by incloſing the liquid, already heated to a certain point, under the receiver of an air-pump and exhauſting the air. If water ſcalding hot be put in this ſituation, a few ſtrokes of the pump will make it boil vehemently, but this laſts only a ſhort time, on account of the cold produced by the evaporation, which lowers the temperature immediately. A further exhauſtion renews the ebullition, a leſs heat being now required, till the cold of the evaporation has again lowered the temperature; and thus the alternate boiling and cooling may be renewed for a conſiderable time.

Ether, which evaporates ſo readily under the common atmoſpherical preſſure and temperature, and which boils at about 102° in the open air, is brought to ebullition at a low heat, ſimply by removing the preſſure, and the cold thus generated (as already mentioned) is very intenſe. This furniſhes a very pretty experiment. Put a little ether (well rectified by waſhing with water) into a thin veſſel of glaſs or metal, incloſed in another veſſel, with a little water interpoſed between the two. Set the whole under the receiver of an air-pump, and exhauſt the air briſkly. The ether will very ſoon begin to boil vehemently and rapidly evaporate, and the cold thereby produced will in a few minutes freeze the water on the outſide of the inner veſſel, and may be taken out as a coating of ice adhering to it. As ſome of the ether ſpurts out during the ebullition, it ſhould be prevented from mixing with the water on the outſide, which would retard its congelation.

Advantage is taken of the cold produced by evaporation to manufacture ice in the tropical climates, where the natural temperature is never ſo low as 32°. At Benares, in the Eaſt Indies, very porous earthen veſſels are employed, and the water conſtantly and ſlowly oozing through them produces by its evaporation ſufficient cold in the night to form a thin coating of ice. (See the article FREEZING.) In Spain, and many of the Mediterranean countries, water is kept conſtantly cool by being kept in porous earthen jars, called in Spain *Alcarazzas*, and in Egypt *Balaſſes*, which furniſh a conſtant evaporation from their ſurface. Bottles of wine and other liquors are cooled by being ſet in theſe jars with water interpoſed.

The evaporation conſtantly going on from the ſurface of animal bodies in the form of inſenſible or ſenſible perſpiration, is the principal cooling proceſs to check the accumulation of heat in the ſyſtem, and it is well known by the feelings of every one how much this evaporation is encreaſed (in the healthy body) by external temperature, exerciſe, and other circumſtances that encreaſe the production of heat. The remarkable experiments of Sir C. Blagden, Dr. Fordyce, and others, in an exceſſively heated room, ſhew that the living animal can exiſt in a *dry* heat even above 212°, that of boiling water, and that the internal temperature remains notwithſtanding nearly at its natural point of about 98°, the enormous exceſs of external temperature being counteracted by the profuſe perſpiration. (*See the article* RESPIRATION.)

The conſtitution of ſome of the permanent gaſſes, or thoſe that remain in a gaſeous ſtate in the temperature of the atmoſphere, ſhews the combination of latent caloric neceſſary to the gaſeous ſtate, though not in ſo marked a manner as the *vapours*. Several of the gaſes

may readily be condenſed into the liquid ſtate by union with water, and ſome by union with each other even paſs into ſolids. In both theſe caſes ſenſible heat ſhould be given out to the ſurrounding bodies, as in the condenſation of ſteam, and this actually happens, though by no means in ſuch quantity. Thus when ſulphuric acid is added to common ſalt, muriatic acid gas is given out in great abundance, and in cloſe dry veſſels it ſcarcely exceeds the temperature of the air at the time, or if ſurrounded with ice may readily be cooled to 32°. But if a large ſtream of this gas be paſſed into water, it is immediately condenſed, uniting with this fluid into liquid muriatic acid, and during the proceſs ſo much heat is given out as to raiſe the liquid even as high as 160°; ſo that in preparing it, it is neceſſary to keep the veſſel artificially cool by wet cloths or ice. The caloric given out is that which was latent in the gas during its aeriform ſtate. Alſo if muriatic gas and ammoniacal gas, both of the common temperature, be mixed together, they inſtantly unite, forming white clouds of ſolid muriated ammonia, and by loſing their gaſeous form ſo much heat is given out as to make the veſſel very ſenſibly warm to the hand. It muſt be mentioned however that the quantity of caloric given out by the permanent gaſſes during their union with ſolids or liquids, is in no degree proportioned to the eaſe with which they are condenſed, and is in many caſes ſo ſmall as to be ſcarcely if at all perceptible by the thermometer.

Of Specific and Abſolute Caloric.

When equal quantities of the ſame ſubſtance, but of different temperatures, are mixed together, the temperature after mixture is very exactly the arithmetical mean, or the middle point between the higheſt and loweſt. Thus when a pound of water at 50° is mixed with a pound of water at 90°, the mixture will be 70° (allowing for the effect of the veſſel itſelf in which they are contained, and taking precautions to avoid any ſenſible error from the temperature of the ſurrounding air.) Now, though the abſolute quantity of heat contained in each pound of water is unknown, it is obvious that the water at 90° contains as much heat as the water at 50°; and in addition, as much as is requiſite to raiſe it 40 degrees of a certain thermometrical ſcale. After mixture the two pounds therefore contain twice as much heat as will raiſe one pound of water to 50°, and beſides, as much as will raiſe one pound 40 degrees. The firſt portion, being permanent, may be put out of the queſtion, and therefore, only conſidering that which forms the exceſs between the two, it appears that as much caloric as will raiſe one pound of water 40 degrees will raiſe two pounds 20 degrees. Now all the experiments on the diſtribution of caloric ſhew that two bodies unequally heated when mixed together will ſooner or later acquire an equal temperature, the cooler body gaining preciſely what the hotter body loſes; and as in the above example the temperature of 70° is the middle point between 50° and 90°, the hotter and the cooler, it appears that equal quantities of heat are required to raiſe equal weights of water the ſame number of degrees of temperature, whatever be the actual temperature before the caloric is added. This inference is confirmed by experiments made at various parts of the range from 32° to 212°.

But if equal weights of *heterogeneous* ſubſtances are employed, the reſult is widely different, the temperature after mixture being never the mean of the thermometrical difference, but ſometimes above, ſometimes below it. Thus if a pound of water at 40° be mixed with a pound of mercury at 69°, the temperature of the mixture will not be 54.5°, the arithmetical mean, but only 41°. Conſequently the mercury has loſt 28 degrees of heat, all of which has been abſorbed by the water, and has only raiſed it 1 degree, and therefore it may be ſtated that it requires twenty-eight times as much caloric to raiſe water to a given temperature as to raiſe an equal weight of mercury to the ſame point. This power of retaining caloric or proportion between the quantity of heat received and the conſequent riſe of temperature, was firſt termed by Dr. Black, *Capacity for Heat*, an expreſſion which is ſufficiently intelligible though not perfectly accurate. It has been adopted by Dr. Irvine and Dr. Crawford, [1] who were among the firſt to elucidate this moſt important ſubject, and to bring to regular demonſtration what was only ſuggeſted by Black. Thus in the inſtance above mentioned, water is ſaid to have twenty-eight times the capacity for caloric that mercury has, becauſe it will hold, or requires, twenty-eight times as much heat, to produce an equal change of temperature. The term *Specific Caloric* is better deviſed to expreſs the ſame thing, that is to ſay, the proportional quantities of caloric requiſite to raiſe equal weights of matter the ſame number of degrees of thermometrical temperature. This is exactly the ſame as the reſpective capacities

[1] Experiments on Animal Heat, 2d edition.

for heat, and the numbers that expreſs the capacities are inverſely as the degrees of temperature to which the ſeveral ſubſtances are raiſed by equal quantities of heat. Thus in the inſtance above given, equal quantities of heat will raiſe mercury 28 degrees and water 1, and therefore the ſpecific caloric or capacity of caloric of the two liquids is inverſely as 28 : 1, or when water is reckoned as unity, mercury will be $\frac{1}{28}$. As all theſe numbers are comparative with each other, and do not expreſs any abſolute quantity of heat, it is neceſſary and convenient to aſſume a common ſtandard of compariſon, and here, as in the caſe of ſpecific gravity, water is the ſtandard fixed upon, and aſſumed to be unity. The ſubſtances compared are alſo generally eſtimated by equal *weights* and not *meaſures*, but the former may be readily converted into the latter by multiplying into their ſpecific gravities. Thus as mercury is (in round numbers) 14 times as heavy as the ſame bulk of water, equal bulks of the two liquids would give 14 pounds of mercury to one pound of water, and if theſe are mixed at the reſpective temperatures of 60 and 40, the mixture will be about 49½, making the reſpective capacities of water and mercury as 1 to $\frac{1}{2}$ with equal bulks.

Two data muſt be aſſumed in this calculation, the one, that equal degrees of the thermometer will meaſure equal inerements of heat; and the other, that the ſpecific caloric of bodies remains the ſame in any temperature, provided the form is unchanged. It has been already mentioned that the expanſion of mercury is nearly, though not rigorouſly, uniform in all the common temperatures at which experiments are made, that is for a conſiderable diſtance above and below the points of freezing and boiling water: and the very accurate experiments of Crawford ſhew that much reliance may be placed on the general poſition that the capacities for heat are equal in the ſame ſubſtance at every temperature, while the form remains the ſame.

The general formula for eſtimating the ſpecific caloric of bodies from the temperature reſulting from the mixture of two ſubſtances at unequal temperatures, whatever be their reſpective quantities, is the following, but it is convenient that one of theſe ſubſtances be water, as it is the ſtandard of compariſon, and its ſpecific caloric is therefore reckoned as = 1. Multiply the weight of water by the difference between its temperature before mixture, and that of the mixture itſelf. Alſo multiply the weight of the other ſubſtance by the difference between its temperature and that of the mixture. Divide the firſt product by the ſecond, and the quotient will expreſs the ſpecific caloric of the other ſubſtance, that of water being 1. For example, ſuppoſe 20 ounces of water at 105° be mixed with 12 ounces of ſpermaceti oil at 40°, and the temperature after mixture be 90°. Then multiply 20 by 15 (the difference between 105° and 90°) = 300: and multiply 12 by 50 (the difference between 40° and 90°) = 600: and 300 divided by 600 will give $\frac{1}{2}$ or .5, which is the ſpecific caloric of the oil, compared to that of water, which is 1. The ſame rule holds when the water is the colder of the two.

The above rule gives the ſpecific caloric of equal *weights* of the two ſubſtances: to make it apply to equal bulks the ſpecific caloric of the ſubſtance compared with water muſt be multiplied by its ſpecific gravity. Thus in the above inſtance if the ſpecific gravity of the oil be .92, the ſpecific heat for equal *bulks* will only be .46, for this converſion into equal bulks is in fact the ſame as diminiſhing the weight, when oil is the ſubject of experiment. Therefore when the compariſon of equal *weights* is converted into that of equal *meaſures* or *bulks*, thoſe ſubſtances that are *lighter* than water will have the number expreſſing the ſpecific caloric *diminiſhed*, and thoſe that are *heavier* will have it *encreaſed*.

Many precautions are required in theſe experiments to enſure tolerable accuracy, and the effect of the veſſel itſelf muſt be eſtimated ſeparately by previous experiment. [m]

The ſpecific caloric of ſolids was aſcertained very early in this enquiry by Wilcke of Sweden, and publiſhed in the Stockholm Academy Tranſactions for 1772. By ingenious calculations he found firſt the quantities of water required to produce a ſimilar effect with that of the ſolid employed, whence the ſpecific caloric was afterwards deduced.

Mr. Leſlie ſuggeſts [o] an elegant and ſimple mode of determing the ſpecific caloric of bodies from obſerving their relative times of cooling a certain number of degrees comparatively with water in ſimilar circumſtances. A very thin glaſs globe, with a narrow neck to receive the bulb of a fine thermometer, is a convenient veſſel for this purpoſe. Firſt fill it with hot water, and obſerve the time required to cool a certain number of degrees, eſtimating always from the temperature of the room, or better a given number of degrees above it, and not from

[m] Crawford. [n] Thompſon's Chemiſtry, vol. i. where they are accommodated to Fahrenheit's thermometer.
[o] Enquiry on Heat, p. 340, 548.

any fixed point on the ſcale: take, for example, the thirty degrees included between the fortieth and the tenth degree above the heat of the room. Let this be a ſtandard and reduce it to unity; then fill the glaſs with any other liquid, and the time of its loſing the ſame thirty degrees will expreſs in *direct* proportion the ſpecific caloric. Theſe reſults only give the ſpecific caloric of equal bulks, to reduce them to equivalent expreſſions of equal weights *divide* them by the ſpecific gravities. Thus Mr. Leſlie found that a very thin glaſs ball of 2½ inches diameter filled with water, cooled a certain number of degrees of temperature in 70 minutes, and when filled with oil it cooled to the ſame point in 32 minutes. Therefore, reducing water to 1., the ſpecific caloric of oil of equal bulk will be .46. This divided by .92, the ſpecific gravity of oil, will give .5 for the ſpecific caloric of equal weights. When ſolids are to be examined they muſt be broken into fragments, put into the glaſs globe, and filled up with water, and the ſpecific effect of the water muſt be ſeparately eſtimated and deducted from that which belongs to the ſolid, by rules of which the reader will find many examples in Crawford's treatiſe. In uſing this apparatus with perfect accuracy, the ſeparate effect of the glaſs ſhould alſo be accounted for, and care ſhould be taken in the cooling to avoid currents of air, or any other circumſtance that might derange the uniformity of the proceſs.

The capacity of gaſſes and vapours differs reſpectively, according to the nature of the gas; and alſo in each individual gas, it varies largely according to its denſity, or the preſſure to which it is expoſed. Every aeriform ſubſtance being a highly elaſtic fluid, is readily dilated or condenſed by diminiſhing or adding to its preſſure, and it is found that ſudden dilatation produces cold in the ſurrounding bodies, and ſudden condenſation gives out heat. Conſequently the capacity for caloric muſt encreaſe by expanſion, and a ſimilar effect, but much leſs in degree, takes place by this proceſs, as in the prodigious expanſion of water into ſteam, or ether into etherized vapour; that is, the abſorption of caloric from all the adjacent parts, in order to ſupply the demand produced by the ſudden encreaſe of capacity for caloric in the vapour.

It has long been obſerved that if a thermometer be encloſed in a ſmall receiver and the air briſkly exhauſted, the mercury rapidly ſinks a few degrees, after which it ſlowly riſes to the common temperature of the room. When the air is again let into the receiver, the thermometer again ſuddenly riſes a few degrees above the common temperature, after which it ſlowly ſettles again to the ſame point, ſhewing the oppoſite effect of condenſation in diminiſhing the capacity for caloric, and conſequently expelling a part of the heat of the air in a ſenſible form. An artificial condenſation of the common air produces a ſimilar effect. This is performed for experiment in a *condenſer*, which is a ſtrong air-tight piſton, by working which an additional quantity of air may be thrown into any confined veſſel. A thermometer encloſed in it riſes ſeveral degrees during the condenſation. The ſame extrication of heat from condenſed air is alſo ſhewn in working the air-gun, which ſoon makes the barrel very ſenſibly hot to the hands; and the blaſt of condenſed air when diſcharged on the bulb of a thermometer ſinks it a few degrees, owing to the cold produced by the ſudden expanſion. This ſtriking occurrence takes place on a vaſt ſcale at the fountain of Hiero, at the mines of Chemnitz, in Hungary. A part of the machinery for working theſe mines is a perpendicular column of water 260 feet high, which preſſes on a quantity of air encloſed in a tight reſervoir. The air is conſequently condenſed to an enormous degree by this height of water, which is equal to 8 or 9 atmoſpheres, and when a pipe communicating with this reſervoir of condenſed air is ſuddenly opened, it ruſhes out with extreme velocity, inſtantly expands, and in ſo doing it abſorbs ſo much caloric as to precipitate the moiſture it contained, in a ſhower of very white compact ſnow, or rather hail, which may readily be gathered on a hat held in the blaſt. The force of this is ſo great that the workman who holds the hat is obliged to lean his back againſt the wall to retain it in its poſition. [p] If the cock of the pipe is only partly opened, the ſnow is ſtill more compact.

Another ſtriking experiment, the direct reverſe of the foregoing (that is the ſudden heating of bodies contiguous to air in the act of condenſation) is given in the Bulletin des Sciences. [q] If the air be very rapidly compreſſed in the ball of an air-gun, ſo great a quantity of heat is diſengaged from it at the firſt ſtroke as actually to ſet fire to a morſel of *amadou* (or fungus match with nitre) encloſed in the ball. If the body of the pump be terminated with a moveable end formed by a piece of ſteel ſcrewed on, and furniſhed in its centre with a glaſs lens, a ray of vivid light will be perceived on the firſt ſtroke of the piſton.

[p] Journ. Phyſ. tom. 48. p. 166.

[q] Phil. Jour. vol. ix. p. 302.

The capacity of the vapour of condenſible fluids appears to be ſtill more encreaſed by expanſion than that of the permanent gaſſes, and conſequently the vaporization of liquids requires more heat when the vapour exiſts in an expanded than in a condenſed ſtate. This circumſtance throws a great obſtacle to the plan of diſtillation in vacuo economically conſidered, which has been propoſed by ſome ingenious perſons, and which at firſt ſight would appear to promiſe many advantages. It is undoubted that a liquid will evaporate and boil in vacuo at a much lower *temperature* than in the free air, but the conſtitution of vapour in this ſituation requires a much greater quantity of combined caloric than when under external preſſure; and conſequently, the advantage gained by boiling at a lower temperature is counterbalanced by the larger quantity of fuel required to furniſh the additional doſe of combined or latent caloric demanded by the vapour when uncompreſſed. The experiments of Mr. Watt firſt proved the truth of this poſition.[r] A ſmall ſtill was half filled with water and very cloſely luted to the worm-pipe of the cooler, which was alſo furniſhed with an air-tight ſtop-cock at the lower end through which the diſtilled liquor drops in common diſtillation. To empty the whole apparatus of air, the water in the ſtill was made to boil violently and the ſteam to paſs through the whole of the worm-pipe uncondenſed, no water being put into the tub of the cooler. This expelled nearly all the common air contained in the veſſels, and the ſtop-cock was immediately cloſed and the fire removed. The ſteam then condenſed, and nearly a perfect vacuum was left in the veſſels. The cooler was then filled with cold water and the ſtill very ſlowly heated, the ſtop-cock at the bottom remaining all the while cloſed. The water diſtilled perfectly well in this vacuum at a very low temperature, and the heat of the ſteam was found to be only 100° inſtead of 212° as in common boiling, ſo that the veſſels ſcarcely felt hot to the hand. But by eſtimating the heat acquired by the water of the cooling-tub during the condenſation of the ſteam, it was found to be ſo much more than what would have been produced by common ſteam, that by calculations ſimilar to thoſe already mentioned, the latent heat of this uncompreſſed ſteam muſt be reckoned at 1048, inſtead of about 840, the heat of common ſteam. With a more perfect vacuum, Mr. Watt found that water would diſtil very well at 70°, but then the latent heat of its vapour approaches to 1300.

[r] Black's Lectures, p. 188.

From the reſult of ſome experiments deviſed with great ingenuity, Mr. Dalton[s] concludes that the heat and cold produced by the mechanical rarefaction and condenſation of air is in fact much more than is indicated by the thermometer (which riſes or falls only a very few degrees), on account of the ſmall ſize of the veſſels uſed in the experiments, and the comparative ſuddenneſs with which the equilibrium is reſtored from without. The rapidity of the change of the thermometer in theſe caſes compared to the time required for an equal change, when the inſtrument riſes or falls a few degrees in the open air, ſeems to confirm the conjecture of a great exceſs of heat or cold acting ſuddenly, and as ſpeedily counteracted; and, among others, the following experiments appear to prove it. A ſmall graduated glaſs tube, 10 inches long, and with a bore only $\frac{1}{15}$ of an inch diameter, was cloſed at the lower end, and a ſhort column of mercury introduced a little way down the upper or open end. The bore of the tube being ſo ſmall, the mercury remained where it was introduced without dropping down, thus ſeparating from the external air that portion of air which was contained in the part of the tube below it, but by its riſe or fall it would readily indicate the expanſion or contraction of this confined portion of air. The tube was introduced under a glaſs receiver of an air pump, to which a condenſer was alſo attached. The receiver therefore would contain two very unequal portions of air, but under the ſame circumſtances of preſſure, the ſmaller portion being that very minute quantity intercepted in the glaſs tube between the mercury and the cloſed extremity, and the larger portion being all the reſt of the contents of the receiver. Now, as the ſmaller portion is cloſely contiguous to a thick wall of glaſs, and is only $\frac{1}{15}$ of an inch in diameter, all the changes of temperature within it, ariſing from rarefaction or condenſation altering its capacity for caloric, may fairly be ſuppoſed to be almoſt inſtantly counteracted, and the equilibrium reſtored by the contiguous parts; but in the larger portion, which includes by far the greater part of a large receiver, a very ſenſible time muſt elapſe before the equilibrium can be entirely reſtored. This time, the author reckons at about 10 ſeconds.

In the firſt experiment, the denſity of the whole air within the receiver was doubled by a condenſer, and of courſe the ſmall column of mercury was preſſed down in the ſmall tube, communicating to the air beneath the ſame

[s] Manch. Mem. vol. v.

preſſure as that above. After a while the cock was ſuddenly opened, the exceſs of air ruſhed out, and the mercury again roſe in a few ſeconds to its former level, and the cock was immediately cloſed. The preſſure from the condenſation was therefore removed, but the cold thereby produced ſtill remained in the air of the receiver, though, for the reaſons above mentioned, it was counteracted in the air of the tube by the heat it would inſtantly abſorb from the glaſs itſelf. The column of mercury then began again to ſink down the tube (the cock being all the while cloſed) and became ſtationary when it had ſhortened of the length of the aerial column by $\frac{1}{10}$. This was obviouſly owing to the expanſion and preſſure of the air in the body of the receiver by the reſtoration of the equilibrium of heat through the ſides of the veſſel, which acted in the ſame manner as the firſt condenſer, and accordingly, when the cock was again opened, air ruſhed *out* of the receiver, and the mercury finally roſe to its firſt level. The next experiment was the reverſe of the former. The column of mercury was firſt let down to within one-fourth of the length of the tube from the ſealed end: three-fourths of the air was then exhauſted from the receiver (which was known by the air in the tube expanding till the mercury reached the top), the ſtop-cock was opened for a few inſtants till the mercury had ſubſided to its former level; it was then ſhut, and the mercury now *roſe* in the tube for five or ten ſeconds to more than $\frac{1}{10}$ of its original height, owing to the *cooling* of the air confined within the body of the receiver, and which had acquired its heat by the ſudden condenſation on opening the ſtop-cock. Accordingly on again opening the ſtop-cock, air ruſhed in, and the mercury ſubſided to its former level. In each experiment a change of about $\frac{1}{10}$ of the bulk of the air of the tube was produced after the equilibrium of mechanical preſſure had been reſtored, and conſequently the whole of this is to be attributed to the operation of the encreaſed or diminiſhed heat; and as a change of 50 degrees of heat is known to produce this quantity of effect on air, it is to be inferred that this change, above or below the common temperature, actually takes place in the receiver in the above experiments. The condenſation of aqueous vapour is very conſiderable in the firſt experiment, where condenſed air is ſuddenly rarefied, the ſudden cold cauſing this watery precipitation; but this does not contribute to the production of the cold, but has a contrary effect, as indeed muſt always happen when a vapour is converted to a liquid form.

It has been already mentioned that in the eſtimation of the ſpecific caloric of bodies they are always ſuppoſed to retain the ſame form, that is, ſolid, liquid, or gaſeous, for it is only then that it can be aſſumed that equal increments of heat produce equal changes of thermometrical temperature. But a knowledge of the ſpecific heat of any ſubſtance will give a ready method of calculating the latent heat, or the quantity of caloric abſorbed during the ſucceſſive paſſage from ſolidity to the ſtate of liquid or vapour. Several experiments on the latent heat of melted metals are given by Dr. Irvine, junr.[1] Biſmuth will furniſh an example. This metal when juſt in fuſion, or when a portion of the melted maſs has begun to congeal, raiſes the thermometer to 476°. A quantity of it perfectly fluid, and amounting to 1555 grains, was poured into a veſſel holding 2236 grains of water at 62°. The heat of the mixture was 86.25°, therefore the water had gained 24.25 degrees, and the biſmuth had loſt 389.75 degrees: and hence 1555 grains of water (that is, equal in weight to the biſmuth) would have gained 34 degrees. Now the ſpecific caloric of ſolid biſmuth compared with water is previouſly known to be .042, ſo that the ſame quantity of heat that will raiſe water .042° will raiſe biſmuth 1°, and conſequently what will raiſe water 34° will raiſe biſmuth 809.5°. But the biſmuth actually loſt only 389.75° of *temperature*, and conſequently the difference between 389.45° and 809.5°, or 419.75°, will expreſs the quantity of latent heat in the melted metal, or that which is loſt when melted biſmuth at 476° is changed into ſolid biſmuth at the ſame temperature. In actual experiment however ſeveral precautions are required and corrections neceſſary, both for the quantity of water diſſipated in ſteam when a melted metal is poured into it, and for the ſmall particles of metal which may be carried off or oxydated, and alſo for the heat acquired by the veſſel in which the experiment is made. Beſides it is well aſcertained that the mercurial thermometer becomes very ſenſibly inaccurate as a meaſure of equal acceſſions of heat when the temperature is very high.

To obviate the objections that ariſe in ſome caſes from the uſe of thermometers as a meaſure of heat, a very ingenious application was made by Meſſrs. La Place and Lavoiſier, of another direct effect of heat, in order to eſtimate reſpective quantities of this ſubtle, imponderous

[1] Ph. Jour. vol. ix.

matter. The thermometer meaſures heat by the expanſion of the fluid employed (which is generally mercury); the *Calorimeter* of La Place and Lavoiſier meaſures it by the quantity of ice at 32°, which it melts under ſimilar circumſtances. This method appears at firſt ſight to be capable of very great accuracy, for ice beginning to melt is invariably at 32°, and the quantity of water produced muſt, if accurately collected, be an exact meaſure of relative quantities of caloric. The calorimeter is a hollow cylindrical veſſel made of tinned iron, and containing three diſtinct concentric cavities ſeparated from each other by circular partitions of the ſame material. The object intended is to place the heated body in contact with or contiguous to ice, ſo inſulated that no heat can get to it but that of the ſubject of experiment. The inner cavity is intended for the heated body; the middle one contains the ice to be melted by it, and for readier communication the partition is perforated all over; and the outer cavity alſo contains ice, which is intended to detain the heat of the external air, and prevent it from reaching the ice of the middle cavity, whilſt the partition between the two keeps entirely ſeparate the melted water of each. A lid ingeniouſly contrived with correſponding partitions ſhuts over the whole. At the bottom are two pipes, one communicating with the outer, the other with the middle cavity. The water from the melted ice drains off through them, that from the outer cavity is not noted, but that from the middle is carefully collected and weighed. Some ſmaller precautions are required, and an extenſion of the apparatus to particular purpoſes,[u] which need not here be enumerated.

As the quantities indicated by the calorimeter are only proportional, ſome ſtandard of compariſon muſt be fixed upon, and this the inventors have determined to be the quantity of caloric neceſſary to melt a pound of ice, which therefore is called 1. This is equivalent to the effect of a pound of water at 135° above 32°, or 167°, which will alſo melt a pound of ice. The example given by Lavoiſier of the application of the inſtrument to other bodies may be here inſerted. A quantity of iron rolled in narrow ſlips, and weighing 7.7070319 pounds, was heated in boiling water to 207.5°, or 175.5 above 32°, and introduced within the inner cavity of the calorimeter. In cooling to 32° it melted 1.109795 pounds of water. Hence it is found by direct proportion that if 175.5 degrees of caloric above 32° will melt 1.109795 pounds of ice :: 135 degrees above 32° would melt 0.85384 pounds. And 135° above 32°, or 167°, is the temperature to which a pound of water muſt be raiſed to melt a pound of ice. Therefore by equal loſſes of *temperature*, 1 pound of water will melt 1 pound of ice, and 7.7.070319 pounds of iron will melt 0.85384 pounds of ice; or (dividing 0.85384 by 7.7070319) 1 pound of iron will melt .1109 pound of ice. Therefore the quantity of caloric given out by iron, is to that given out by water, at equal differences of temperature, as .1109 to 1.

In meaſuring temperatures near the utmoſt limit of the ſcale of the mercurial thermometer and upwards, the calorimeter may certainly be made a valuable inſtrument; but it appears from ſome experiments by the late Mr. Wedgewood,[v] that it is ſcarcely poſſible to ſeparate with accuracy the melted water from the ice remaining in the middle cavity of the inſtrument, and even, as it ſhould ſeem, a portion of the thawed ice again freezes, ſo as to throw much uncertainty on this method of eſtimating relative quantities of caloric.

The attempts that have been made by ſeveral very accurate experimentaliſts to weigh caloric need not be particularly deſcribed. Fordyce, Lavoiſier, Rumford, and Higgins, have each inſtituted experiments with great care, but the reſults of none prove unexceptionably that any weight can be attributed to caloric, or that any ſubſtance within the reach of human inſtruments weighs leſs when cold than when hot, no other change having taken place than the mere loſs of caloric. In balances that are adjuſted with extreme accuracy, the vicinity of a hot body to one end of the ſcale beam will readily expand it enough to deſtroy for a time the equilibration; and if this cauſe of error is avoided by allowing a conſiderable time to elapſe between the weighing of the ſubſtance before and after the loſs of heat (it being at the temperature of the atmoſphere in each caſe) a ſlight change may probably have taken place in the weight of the air, amounting to a ſenſible difference of the barometer, which will cauſe an additional difficulty in theſe delicate reſearches. Even if ſome aſcertainable weight could be found to a conſiderable quantity of caloric, it is obvious that the balance could never be practically employed as a ſubſtitute to the thermometer.

Of Abſolute Caloric.

The ſpecific caloric of a body has been ſhewn

[u] Mem. de l'Acad. for 1780, or Lavoiſier's Chemiſtry, p. 421. [v] Phil. Tranſ. vol. 74.

to be the proportional quantity of caloric neceſſary to raiſe its temperature any given number of degrees, compared with that required to raiſe an equal weight of any other body, and eſpecially water, which is the ſtandard generally agreed upon. The proportions between theſe reſpective quantities are aſſumed to be the ſame at any actual temperature, provided the reſpective ſtates remain unchanged, that is, provided ſolids remain ſolid; liquids, liquid; and gaſſes, gaſiform. For example, it requires twice as much caloric to raiſe tin to any given point as it does to raiſe lead to the ſame, or, expreſſed in the proportions to water, the ſpecific caloric of tin, according to Dr. Crawford, is .070, and of lead is .035, and theſe proportions are ſuppoſed to be the ſame from the loweſt poſſible temperature to any degree ſhort of the melting point of tin, which is the moſt eaſily fuſible of the two. Conſequently, if they could be put in a ſituation to be deprived of all their caloric of temperature, the tin would loſe exactly double the quantity that the lead would do, and therefore at all equal temperatures the abſolute quantity of heat contained in tin is double that of the lead.

This leads to the enquiry into the *real zero*, or the point of *abſolute cold* meaſured by an equidifferential thermometer, for though ſuch a thermometrical meaſurement is practically impoſſible, the ſcale may be hypothetically extended indefinitely to any diſtance below the actual zero. It may be premiſed that there is no reaſon to ſuppoſe that any degree of cold, natural or artificial, ever obſerved, has approached the term of abſolute privation of temperature. Formerly the zero of Fahrenheit was ſuppoſed to be this point, but an actual cold of at leaſt 40° lower is now procurable without much difficulty in the congelation of mercury, and by particular means a cold of much greater intenſity may be produced, though the meaſurement below this becomes very uncertain, for want of an unexceptionable liquid for the thermometer when mercury becomes uſeleſs. Even in the moſt intenſe cold ever produced, pure alcohol remains fluid, and the permanent gaſſes retain their gaſeous form, but from analogy we may reaſonably ſuppoſe that alcohol owes its fluidity to the combination of caloric, and perhaps that the gaſſes themſelves might be brought to a liquid or ſolid ſtate by abſtraction of heat. However as the leaſt computation of the real zero places it at leaſt five times the diſtance between freezing mercury and boiling water below any obſerved cold, no material objection can ariſe to theſe computations from the probable effect of abſolute cold on the hitherto uncongealable bodies.

The late Dr. Irvine, of Glaſgow, was the firſt who inſtituted a theorem for the determination of the real zero, and this ſubject has been further examined by Crawford, Gadolin, and many other very accurate experimenters. Unfortunately there exiſt ſuch material objections to the data which muſt be aſſumed as the baſes of theſe calculations that a ſhort notice in this place will ſuffice.

Dr. Irvine's moſt ingenious theory is founded on the compariſon between the ſenſible heat given out when a ſubſtance paſſes from a ſtate of greater to a leſs capacity for caloric, and the difference between the capacity in each ſtate: thus it is aſcertained that about 140 degrees of heat are given out when water is converted to ice (or, what amounts to the ſame, that ice at 32°, in thawing abſorbs as much heat as would raiſe water at 32° to about 172°) and the capacity of ice is to that of water as 9 to 10. Water therefore contains as much *abſolute* caloric as ice, and 140 degrees additional; and it is aſſumed that the abſolute caloric of water compared to that of ice, is as their ſpecific calorics, or as 10 to 9: and hence it follows that 140° is one-tenth of the abſolute quantity contained in water, or that the entire quantity is 1400°. Or in other terms, the difference of the capacities before and after the change, is to the capacity after the change, as the ſenſible heat produced is to the whole number of degrees of heat which the body contained previous to the alteration in its form.

Another method given by Dr. Irvine of aſcertaining the quantity of abſolute heat is by the difference of temperature that generally reſults from the mixture of two bodies, compared with their reſpective capacities for heat. Sulphuric acid and water are very convenient examples, as the ſenſible heat evolved on mixture is very conſiderable. To render it a meaſure of the abſolute heat, it ſhould be produced merely from the capacity for heat of the mixture being leſs than the mean capacities of the two before mixture, relative to their reſpective weights. [w] It unfortunately happens that experiments made with different mixtures by no means correſpond or approach ſufficiently to a correſpondence to enable us to aſſume the neceſſary datum that the change of temperature only ariſes from a change in the capacity after mixture, and there-

[w] Crawford.

fore we ſhall merely refer the reader to Dr. Crawford's Treatiſe (p. 453 and ſeq.) for the calculations on this curious experiment.

It is alſo forcibly objected by Dr. Robiſon* that it is highly improbable that the proportion between the actual loſs of caloric and the diminution of temperature (or the ſpecific heat) remains the ſame towards the extremity of the ſcale of actual privation of heat as it does at the higher temperatures, the form ſtill remaining unchanged. So that, though the calculations of ſpecific heat may hold good experimentally in all practicable caſes, it does not follow thence that the inference deduced from them can be extended to the extreme hypothetical diſtance which the determination of the actual zero would require. It is more analogous to other phenomena, as Dr. R. obſerves, to ſuppoſe that in the temperatures nearer to that of abſolute privation, the quantities of heat neceſſary for producing equal elevation gradually diminiſh, as in moſt other progreſſions of natural operations. The hypotheſis of Irvine and Crawford alſo ſuppoſes an equal uniformity in the comparative diminution of temperature in different bodies, to allow of the ſame point of abſolute cold for all ſubſtances in nature. But it is equally improbable that this uniformity holds good for different ſubſtances at all temperatures, and hence we cannot with any certainty infer the abſolute heats of different bodies from the eſtimation of the comparative ſpecific heats that are within the limits of experiment.

The evolution of caloric by the mixture of different ſubſtances will be further noticed in the next ſection concerning

THE SOURCES OF CALORIC.

The two great ſources of caloric that we are acquainted with, and whoſe mighty operations are conſtantly before our eyes, are the ſun's rays and combuſtion. The great proceſſes in nature and art that demand a ſupply of this principle receive it chiefly either from ſolar rays or culinary fire; but there are beſides ſome other ſources of caloric of conſiderable extent and importance, which cannot be arranged under either of the foregoing heads, and require a ſeparate notice.

Of Chemical Mixture and Change in Capacity.

The evolution of ſenſible heat from any ſubſtance or ſubſtances when their ſpecific caloric, or capacity for heat, is diminiſhing, has already been explained. Experiments on this head are the exact converſe of the freezing proceſſes by mixtures where the capacity is ſuddenly encreaſed; and it is ſo ſeldom that chemical action takes place between different ſubſtances, without a very ſenſible change in the capacity for caloric, that a riſe or fall of the thermometer above or below the arithmetical mean may generally be expected on the mixture of bodies that have an affinity for each other, and is conſidered as a proof of intimate or chemical action. This ſource of caloric, though ſeldom acting with any great energy in natural proceſſes, muſt in many inſtances be able, by its conſtant operation, to afford an adequate ſupply for very important changes. Dr. Crawford has with great ingenuity of reſearch traced to this ſource no inconſiderable portion of the heat perpetually maintained in the living animal above the common temperature, having ſhewn that the arterial blood has a greater capacity for heat than the venous, and conſequently that it muſt, on this account, give out ſenſible caloric in the natural progreſs of the circulation. Likewiſe all the proceſſes, natural or artificial, in which gaſſes are abſorbed and condenſed by liquids and ſolids, or liquids by ſolids, muſt be heat-evolving proceſſes from the diminution of capacity attending theſe changes of ſtate.

Some of the moſt powerful and familiar inſtances of the evolution of heat from mere mixture without a change of ſtate, are, on adding water to alcohol, and to the nitric, and eſpecially to the ſulphuric acid. With the laſt, the heat produced on mixing nearly equal portions is much above that of boiling water.

In all theſe inſtances it has been attempted to be ſhewn by Drs. Irvine, Crawford, and others, that the evolution of caloric was very exactly proportioned to the change in the ſpecific caloric, and indeed the calculations on the ſubject of abſolute caloric require this proportion to hold uniformly. So that according to theſe philoſophers, the caloric can hardly be ſaid to be *chemically* united with the bodies that evolve it on mixture when the capacity is leſſened, and the term *capacity* is ſomewhat better adapted to their conception of the mode of union.

But it has been ſhewn that a mere change of capacity will not account conſiſtently for all the caſes of evolution of heat on mixture, for there is an utter want of tolerable correſpondence in all the calculations that have been made of the real zero derived from very different ſources. The vaſt quantity of caloric given out in the ſlacking of well-burnt lime cannot be brought to tally with the proportional quantity that appears on mixing ſulphuric acid and water (for

* Notes to Black's Lectures.

example) relatively with the mutual capacities; and hence we are compelled to incline to the hypothesis (in itself by no means strained or improbable) that caloric may truly and chemically combine with bodies and lose all its distinguishing characters, till it is expelled by stronger affinity, as any other body loses its specific characters by chemical union, and regains them as soon as that union is broken. Thus, in the above example of lime, it is certain that a part of the heat arises from the solidification of the water, or its change of state from a fluid to a solid; and another part perhaps arises from the capacity of slacked lime being less than the mean capacities of the lime and of water, but a third portion may be ascribed with high probability to the expulsion from the lime of a quantity of caloric, owing to the elective affinity of water being the strongest of the two. This caloric would readily be furnished by the fuel during the previous burning of the lime, and hence this earth in its *quick* or *caustic* state might perhaps be considered as a compound of lime and caloric, exclusive of that quantity of caloric which is inherent in all natural bodies, and which is alone considered in the estimation of *specific* caloric.

As an additional argument for this chemical combination of an excess of caloric in quick-lime, it may be added that calcined Plaster of Paris will absorb and render solid to the full as much water as lime will, but with scarcely any change of temperature, and yet the substance whose change in capacity is the most reduced by the combination (that is, the water), is the same in both instances.

Many other examples of violent heat on mixture might be adduced, which seem to demand the hypothesis of a chemical union of caloric in one or other of the substances: but some of them, such as the heat and inflammation produced by the nitric and oxymuriatic acids, belong to the subject of combustion.

Of Friction and Percussion.

The heat which is elicited by (apparently) simple mechanical means, by rubbing, hammering, and the like, cannot be satisfactorily referred to change of capacity, or to combustion, and so little is yet known on this head that we must be content with the mention of the facts. The heat from percussion is very well shewn by the method often used by blacksmiths, of hammering a piece of cold soft iron till it is quite hot enough to kindle a sulphur match. This is performed in a few minutes by vigorous hammering. It is to be observed that iron thus treated becomes much harder and denser, and when cold cannot again be brought to the same heat by the same means, unless it is first *annealed*, that is, heated red hot in the fire, and allowed to cool spontaneously in the air, when it again returns to the state of soft iron. The rudeness of the experiment renders it impracticable to estimate the absolute quantity of caloric given out during the hammering, but as it is obviously connected with the alteration of the texture of the metal, some have supposed that the heat is forced or squeezed out by a simple mechanical action, somewhat in the way that water is squeezed out of a moist sponge; and hence that the annealing causes a quantity of heat to adhere to the metal by a very loose combination. In all the cases of the evolution of caloric by percussion, the substance decreases in capacity for caloric, in proportion as its density encreases. Thus, metals become heated by lamination, and when denser, their specific caloric is less than before. No heat is produced in dense fluids by the mutual friction or percussion of their particles in any way, and fluids are nearly incompressible, so that their capacity for caloric cannot be altered by mechanical means. On the other hand the compression of gasses produces very considerable heat, as in the air-gun experiments and others already related. These facts would indicate that the cause of the heat from percussion and mechanical compression was simply the change in the capacity for caloric; but though this is certainly true to a considerable extent, it does not appear that the evolution of caloric is uniformly proportional to the change in capacity, and the phenomena of friction point out a distinct and hitherto inexplicable source of caloric which may combine its action, in many cases of percussion, with the proper effects of change in specific caloric.

The examples of the production of heat by friction are innumerable. Wherever machinery requiring rapid motion is used, every one knows the heat which is produced, and when the machinery is combustible, the great precautions requisite to avoid its destruction by the heat which its motion excites. The use of lubrication is not more to lessen the mechanical obstacles to free motion, than to prevent the great accumulation of heat by friction. Ungreased carriage wheels taking fire, gunpowder or cotton mills destroyed by overheating the machinery, are familiar examples of this fact: and the method still employed by man in the

ſavage ſtate to kindle fire, is well known to be the friction of two ſticks or other combuſtible ſubſtance.

In exciting heat by friction it is obvious that the hardeſt bodies are thoſe which, *ceteris paribus*, would produce the greateſt mechanical impediment, and therefore ought to give out the moſt heat. Thus a hard twiſted cord drawn violently through the hand will produce a more ſevere burn than the ſame looſely twiſted. But the hardeſt bodies, ſuch as metals and ſtones, are alſo the beſt conductors of heat, and hence it may often happen that a given intenſity of heat will be ſooner accumulated in a ſoft ſubſtance of difficult conducting power than in the hardeſt metal.

Mr. Pictet found in ſome experiments on friction [y] that much more heat was produced by the friction of wood on wood, than of braſs on braſs, and the moſt of all when a few filaments of cotton were interpoſed.

The moſt accurate, and from the large ſcale in which they were carried on, the moſt ſtriking experiments on the heat ariſing from friction, are thoſe which Count Rumford [z] made at the ordnance-foundery at Munich, with the machinery employed to bore cannon. The leading particulars are the following: a cylindrical piece of braſs (being a waſte portion of a ſix-pounder braſs cannon) weighing about 113 lb. was fixed in the boring machine, and a blunt ſteel borer was introduced and forcibly preſſed againſt the inſide with a preſſure equal to the weight of 1000 lb. The cylinder itſelf was then made to revolve on its axis, and thus to work againſt the bore (as in the uſual method of hollowing cannon) by a two-horſe power. The cylinder was wrapped up in flannel to retard the diſperſion of heat. In 30 minutes (or after 960 revolutions) a thermometer laid in contact with the cylinder in a place hollowed out for its reception, roſe from 60° to 130°, ſo that the temperature of at leaſt 113 lb. of metal had been raiſed 70 degrees, and this quantity of heat would have been ſufficient to boil 5 lb. of ice-cold water. To prevent all poſſibility of any portion of this heat having been furniſhed by the air, Count Rumford repeated the experiment with an ingenious contrivance for cauſing the borer to work in vacuo, and an equal effect was produced as in the former caſe. The third experiment was ſtill more ſtriking. The whole apparatus was incloſed in a water-tight box, and covered with about 2½ wine gallons of water at 60°, and the borer ſet in motion. The heat thereby generated was communicated to the water, the temperature of which roſe in one hour from 60° to 107°; in half an hour more to 142°; in another half-hour to 178°; and in twenty minutes more it actually boiled. Thus therefore 2¾ gallons of water were heated 152 degrees by ſtrong friction for two hours and twenty minutes, beſides an equal riſe in the temperature of the braſs cylinder, weighing 113.33 lb.; of 36¾ cubic inches of iron and ſteel in the borer and other apparatus, beſides what was diſperſed in the air and communicated to the box. By very fair eſtimation, the whole heat thus generated was more than equal to have raiſed to the boiling point 26.58 lbs. averdupois of water at 32°: or (by inference from ſome of Dr. Crawford's experiments) it would have required the united effect of more than nine wax candles three-quarters of an inch in diameter, and applied in the moſt advantageous manner, to have heated as much water to the ſame point.

In the above experiments the queſtion ariſes whence this large acceſſion of heat could have been derived? It is obviouſly generated by the friction, and apparently in a very uniform manner; but no other ſenſible effect is produced by the borer than that of turning out a large quantity of fragments of braſs (ſomewhat reſembling wood ſhavings in form) and poſſibly, by the great preſſure, a ſlight condenſation of the remaining hollow cylinder of metal. But the turnings of the braſs come out quite bright and metallic, and have undergone no obvious chemical alteration whereby caloric could have been elicited, and therefore we muſt either account for the heat by the diminiſhed capacity for caloric of the braſs turnings, or acknowledge friction to be a ſource of heat entirely diſtinct from any we have hitherto examined. To aſcertain the capacity of the braſs turnings, Count Rumford added 1016.5 grains of them at 210°, to 4590 grains of water at 59.5°, and the common heat after mixture was 63°, whence by Crawford's rule the ſpecific caloric of the braſs turnings is .110. An equal quantity of thin ſlips of gun-metal cut out by a fine ſaw was examined under ſimilar circumſtances; and the common temperature and of courſe the ſpecific heat were found *preciſely the ſame*. Hence (even allowing a little higher ſpecific caloric in *caſt* braſs over the turnings from the borer) the utmoſt effect of this could only account for a very minute portion of the actual heat produced by the friction, nor is it probable or even poſſible that

[y] Eſſai ſur le Feu.

[z] Phil. Tranſ. 1798.

any ſimple condenſation of the ſides of the remaining hollow cylinder of braſs would do more. Friction therefore is a totally diſtinct ſource of caloric, and apparently unlimited in its action; for as long as it is kept up, the evolution of heat continues uninterruptedly, nor has any approach been made to an exhauſtion of the ſupply. In this reſpect it differs from percuſſion. It may be added that the moſt powerful arguments againſt the materiality of caloric are drawn from this ſource.

Of Solar Heat.

The direct paſſage of caloric from the ſun, and Dr. Herſchel's important diſcovery of calorific rays ſeparate from thoſe that occaſion light and colour, have already been noticed under the head of *radiant caloric*. Some other of the chemical facts connected with the ſolar rays will be deſcribed under the article LIGHT.

The intenſity of the heat produced by the direct rays of the ſun, collected by a lens or reflected by a concave ſpeculum, is equal, with powerful inſtruments, to any other method of raiſing heat; but of courſe it muſt be confined to a very ſmall ſpot. Solar heat, when it can be procured ſteady and for a ſufficient length of time is moſt admirably adapted for very delicate and complicated experiments, as no error can ariſe from the introduction of burning fuel: and with caution, the pencil of rays from a lens or mirror may be tranſmitted through a glaſs veſſel to any object contained within it.

The heat of the direct rays of the ſun (ſimply thrown on any object without being collected by any glaſs or mirror) is much greater than generally appears by the thermometer, much of it being diſperſed by the air through which it is tranſmitted, eſpecially when in briſk motion. When the ſun's rays are confined to any ſpot, as much as may be, by being ſurrounded with bad conductors and protected from wind, the accumulated heat eaſily riſes to a much greater intenſity than the higheſt temperature of a tropical ſun. M. de Sauſſure made an experiment to this point.[a] He made an oblong box one foot long and nine inches in width and depth, of half-inch deal, and lined it on the inſide with cork an inch thick, and charred on the ſurface. A cover was fitted on, made of three panes of glaſs cloſe fitting and parallel to each other, with 1½ inch of ſpace between each. When this was ſet in a hot ſun the heat had to penetrate the three glaſſes, and was conſtantly accumulating in the box to a given degree, being confined on the three ſides by the burnt cork and thick walls of the box, and on the fourth by the two ſtrata of air at reſt contained between the glaſſes; all bad conductors of heat. On the top of a high peak of the Alps (on which for a particular purpoſe the experiment was firſt made) the box was expoſed to the ſun's rays for a conſiderable time, and a thermometer, which in the free air (hung 4 feet above the ground, and in the full ſun-ſhine) ſtood only at 45½°, roſe gradually within the box to 190½°. The riſe of the laſt 46 degrees was effected in an hour. The thermometer laid on a piece of charred cork in the open air roſe to 79¼°. At the bottom of the mountain, nearly 800 fathom lower, the reſpective temperatures under ſimilar circumſtances of expoſure were, ſuſpended in the free air 74¾°, within the box 187½°, and laid on cork 92¾°. Similar experiments by Profeſſor Robiſon[b] gave a much greater effect, the thermometer riſing within the box to 230° and 237°.

Of Combuſtion.

The laſt ſource of caloric to be mentioned is that which appears, in union with light (together conſtituting *Fire*) in the proceſs of combuſtion: and the heat employed for all culinary, domeſtic, and manufacturing purpoſes, is almoſt entirely derived from this ſource.

The neceſſity for a conſtant ſupply of air to maintain combuſtion in all common caſes, firſt led chemiſts to the important analyſis of atmoſpherical air, and the diſtinct properties of that conſtituent of air which alone is active in maintaining combuſtion and reſpiration, and to which the modern ſyſtem of nomenclature has given the name of OXYGEN. Under this article, and that of PHLOGISTON, the different theories of combuſtion will be deſcribed, but it may be here added that the caloric contained in oxygen and given out during combuſtion is not ſolely that which is requiſite to the gaſeous ſtate, but in all probability is an eſſential conſtituent of this ſubſtance.

When a ſolid ſubſtance is burnt in oxygen *gas*, and the reſult is a ſolid or liquid, it might indeed be ſuppoſed that the evolution of caloric was owing to the change from the gaſeous ſtate to one of much leſs capacity for heat; but in a variety of inſtances the caloric produced by combuſtion is by no means proportioned to the quantity of oxygen gas conſumed, and what entirely overthrows this hypotheſis is the intenſe heat given out by gunpowder and various other combuſtible mixtures with the nitric or oxymuriatic ſalts, in which the oxygen is not in

[a] Voyages dans les Alpes, tom. 2. p. 365.

[b] Notes to Black's Lectures, p. 547.

the ſtate of gas, but on the contrary is ſolid and condenſed, and therefore can contain no caloric but that which muſt be conſidered as one of its eſſential conſtituents.

For the connection of light with caloric, ſee the articles LIGHT, OXYGEN, and PHLOGISTON.

CAMELEON MINERAL.

The chemical compound known by this name is ſo called on account of the changes of colour which it exhibits. It is thus prepared. Take one part of common black oxyd of manganeſe finely levigated, mix it with five parts of puriſied nitre, and fuſe the maſs for about half an hour at a high heat in an earthen crucible. A dark green maſs is thus produced, which deliquiates on expoſure to the air, and muſt therefore be kept in a well ſtopped vial. This ſubſtance readily diſſolves in hot water, making a dark green ſolution: after the ſolution has been kept for a few days in a cloſe veſſel, a yellow powder begins to precipitate, and the liquor becomes of a fine blue: this blue liquor being diluted with common water aſſumes a violet colour, which afterwards grows red, and finally loſes its colour, a grey oxyd of manganſe being thrown down; by the addition of a few drops of acid to the blue liquor the change to red is inſtantaneous, and the colour is a very beautiful tint between crimſon and pink. The cauſe of theſe changes is probably the following.

Black Manganeſe conſiſts of the mixed oxyds of Manganeſe and Iron, both of which are ſoluble by fuſion in cauſtic alkali: the natural colour of alkali with manganeſe is blue, and that of iron with the ſame is yellow: by the union therefore of theſe colours a green is produced. When the ſolution has been kept a few days the oxyd of iron ſeparates, and the green colour being deprived of its yellow part becomes blue. Oxyd of manganeſe in a very finely divided ſtate is of an amethyſtine red colour, as ſoon therefore as the oxyd of manganeſe begins to quit the alkali, the blue liquor becomes mixed with red particles and therefore is at firſt violet; and, as the red particles increaſe, becomes pink; finally, when the manganeſe is entirely precipitated the liquor loſes its colour, and the metallic oxyd by having its particles condenſed, becomes of a blackiſh grey.

CAMPEACHY WOOD. See LOGWOOD.

CAMPHOR. *Kampher*, Germ. *Camphre*, Fr.

Camphor is a colourleſs tranſparent ſubſtance, of a granular or foliated fracture, and a conſiderable reſinous luſtre: it is ſomewhat unctuous to the feel; it poſſeſſes a certain degree of toughneſs, yet may be crumbled between the fingers without difficulty. It has a penetrating fragrant and highly refreſhing odour; to the taſte it is bitter and penetrating, rather heating at firſt, and afterwards remarkably cooling. It is volatile in a moderately warm temperature, and may be melted by heat ſuddenly applied. It burns with a large white flame and denſe ſmoak. Its ſpecific gravity is $=0.996$, ſo that it juſt floats on the ſurface of water, and very ſmall pieces thus floating may be ſet fire to, and will continue burning till they are almoſt entirely conſumed. Camphor is the produce of a large foreſt tree, the *Laurus Camphora*, which grows wild in Borneo, Sumatra, and probably in ſeveral other of the Indian iſlands. The leaves of this tree give out when bruiſed a very ſenſible odour of camphor. The camphor itſelf is found concreted in perpendicular veins near the centre of the largeſt and oldeſt trees, eſpecially thoſe which have not been pierced when young for the ſake of the fragrant camphorated oil which they contain.* The tree being cut down and ſplit, the camphor is picked out by means of knives, and the ſmaller pieces are ſeparated from the wood by raſps. The camphor according to its purity is divided into three ſorts, the two inferior of which are mixed with certain proportions of a coarſe kind procured by diſtillation from the native oil of the tree. The preparation of each kind for ſale is ſimply by waſhing in warm ſoap and water. In Japan alſo is found a ſpecies of Laurus which yields camphor, but not in ſuch quantity as the Laurus Camphora. It does not appear to be contained in a concrete ſtate in this tree: but the roots and ſmaller branches afford it by diſtillation. For this purpoſe the roots being reduced into thin chips, and mixed with the twigs, are put into a net and ſuſpended within a kind of alembic, at the bottom of which is a little water: by the application of a boiling heat the ſteam penetrates the contents of the net, and carries the camphor along with it into the capital, where it is depoſited like ſnow on the ſtraw with which the capital is lined. The Sumatran camphor is much more eſteemed in the Eaſt than the Japaneſe, on account of a certain adheſiveneſs which it poſſeſſes, and in conſequence of which it is much leſs volatile than that which has been obtained by diſtillation. All the camphor which comes to Europe is the produce of Borneo or Sumatra; and it arrives in the form of irregular pieces of a yellowiſh grey colour which are

* Aſiat. Reſearches, vol. iv. p. 19.

ſpungy and very light, and when broken ſhow that they are compoſed of ſmall cryſtalline grains. The rough camphor is mixed with a very minute quantity of earth, from which both its colour and a ſlight grittineſs between the teeth are derived.

The purification of crude camphor is an art which is carefully kept a ſecret by thoſe who are in poſſeſſion of it. Formerly this proceſs was carried on only at Venice, afterwards it was ſucceſsfully practiſed in Holland, and at preſent large quantities are refined by ſome of the Engliſh druggiſts. If the crude camphor is contaminated merely by earthy particles, the purification may be effected by ſimple ſublimation without any addition; but as in ſome caſes at leaſt, the Dutch are in the practice of mixing lime or chalk in ſmall proportions, it is probable that this addition is found of uſe in keeping down the oil with which the crude camphor is ſometimes mingled. Spirit of wine has been propoſed and employed on a ſmall ſcale for the purification of camphor, but this menſtruum beſides being ſomewhat expenſive, is incapable of ſeparating any reſinous ſubſtance which the crude article may contain.

Simple ſublimed camphor differs from the refined camphor of the ſhops in being of a ſomewhat ſpungy granular conſiſtence, but it may be made to aſſume the cloſe and foliated texture of the latter by fuſion, which is underſtood to be the method practiſed in the refineries: this may be done either by increaſing the heat ſuddenly when the ſublimation is almoſt ended, without transferring the camphor to different veſſels, or by melting the ſublimed flowers in a veſſel for that purpoſe.

Although the camphor of commerce is obtained only from the Laurus Camphora, and a kindred ſpecies in Japan, yet its exiſtence has been proved in many other ſpecies of Lauri; thus the roots of the Cinnamon tree *(Laurus Cinnamomum)* of the Saſſafras *(Laurus Saſſafras)* of the Caſſia *(Laurus Caſſia)* may be made to yield real camphor by diſtillation, though not in ſufficient quantities to counterbalance the expence. The diſtilled water from the flowers of the Anemone pratenſis has been found to depoſit cryſtals of camphor by long ſtanding.[b] It has alſo been diſcovered in the freſh roots of Galangale *(Maranta Galanga)* Zedoary *(Kæmperia rotunda* and ginger; and in the ſeeds of cardamom and long pepper. It is probably contained in all the eſſential oils, and has been actually procured from thoſe of juniper, ſage, hyſſop, thyme, pepper-mint, roſemary, and lavender. The depoſition of cryſtalline grains ſimilar to camphor was firſt obſerved by Slarius in ſome old oil of cinnamon. Kunkel and Lewis confirmed this fact, and ſupplied ſome others of the ſame nature; Geoffroy, Cartheuſer and Gaubius extended their experiments to moſt of the eſſential oils; and finally, Prouſt has taken the ſubject in hand, and from accurate and large experiments has ſhown that camphor may be profitably prepared from the eſſential oils in the ſouthern countries of Europe.

This eminent chemiſt having accidentally obſerved[c] that the eſſential oil of lavender diſtilled in Murcia, depoſited a large proportion of camphor, and that the other oils of this province were remarkably fragrant, ſelected the eſſential oils of roſemary, marjoram, ſage, and lavender, as the ſubjects of the following experiments. Equal portions of the four oils were placed in ſhallow earthenware veſſels, and expoſed to ſpontaneous evaporation at a temperature not exceeding 57° of Fahren. and in proportion as the cryſtals of camphor were depoſited they were taken out and drained, and kept in well ſtopped vials: by this ſimple proceſs the oil

of roſemary yielded 6.25 per cent. of camphor
— marjoram —— 10.14 ——— of camphor
— ſage —— 21.06 ——— ———
— lavender —— 25. ——— ———

The oil of lavender appears to be fully ſaturated with camphor; for although when heated it will take up about $\frac{1}{16}$ of its weight more of this ſubſtance, yet by cooling it depoſits even a larger quantity than it was made to diſſolve. When expoſed to ſpontaneous evaporation the firſt filaments of camphor begin to appear in about twelve hours, and continue to be depoſited till almoſt the whole is evaporated. In the other oils the cryſtals were later in ſhooting according to their relative proportions of camphor; and when about four-fifths of the oil was evaporated the reſidue became thick, and ceaſed to yield any more cryſtals. The camphor produced by each of the four experiments being dried by ſlight preſſure between filtering paper was in dry, almoſt pulverulent cryſtals, as brilliant, and almoſt as white as ſnow, and ſo little of the peculiar odour of the oil remained, that it was by no means eaſy to aſcertain by the ſmell alone from what ſpecies of oil any particular parcel of cryſtals was obtained.

The proportion of camphor procurable from theſe oils depends in ſome degree on the rate at which the evaporation proceeds, the quantity

[b] Crells Chemiſche Journ. vol. i. p. 102.

[c] An. de Chim. iv. p. 179.

being in an inverſe ratio to the temperature. If oil of lavender is diſtilled from a water bath in an alembic, at a temperature inferior to boiling water, till one-third is come over, the remaining two-thirds will depoſit flakes of camphor while cooling, theſe being removed, and the diſtillation being repeated, a freſh depoſition will take place in the reſidue, and a third diſtillation will yield all the remaining camphor except about $\frac{1}{2}$ per cent. This however being a much more rapid proceſs than ſpontaneous evaporation, the total produce of camphor from the three diſtillations does not amount to more than 20 per cent. the reſt being held in ſolution by the oil in the receiver. If the *balneum mariæ* is made to boil, the produce of camphor will be conſiderably diminiſhed, and part will ſublime into the capital of the alembic. The camphor from oil of lavender by either of theſe methods is not abſolutely pure, for when ſublimed *per ſe*, at a gentle temperature, it leaves behind a ſmall portion of browniſh reſin ſtill mixed with a little camphor. The moſt economical way of refining this camphor is to mix it with half its weight of chalk, or lime, or waſhed wood aſhes, and ſublime it, by which operation it loſes $\frac{2}{15}$ of its weight. The produce of refined camphor therefore by ſpontaneous evaporation of oil of lavender amounts to about 24 per cent. and by diſtillation is equal to 19 per cent.: this latter method however is by far the moſt economical, notwithſtanding the additional expence of fuel and apparatus, as it ſaves both time, and the oil, which would otherwiſe be entirely loſt.

The production of camphor by the action of muriatic acid on oil of turpentine is a diſcovery of very late date, and though it ſtill requires ſome further elucidations, the leading facts appear ſufficiently confirmed to juſtify their inſertion in this place.[e] M. Kind, while preparing the arthritic liquor of Pott by paſſing muriatic acid gas through oil of turpentine, obſerved the mixture to depoſit by cooling, a large quantity of cryſtals poſſeſſed in almoſt every reſpect of the characters of camphor. The experiment was repeated by Trommſdorff with the ſame reſult; and the ſociety of pharmacy at Paris being informed of theſe facts, nominated three of their members to repeat the inveſtigation, and make a report on the ſubject. From theſe ſources the following information is derived.

A ſmall quantity of camphor may be obtained from oil of turpentine ſimply by diſtillation, provided this proceſs is carried on ſufficiently ſlowly. Eight ounces of this fluid were diſtilled in a glaſs alembic at about the temperature of 124° Fah.; four ounces of very highly rectified eſſential oil paſſed into the recipient, and the capital was found lined with ſmall cryſtals of real camphor.

This ſubſtance is however procured in much larger proportions by the affiſtance of muriatic acid. Four pounds of oil of turpentine were put into a Woulfe's apparatus, and the retort being charged with the ſame weight of decrepitated muriat of ſoda, and half as much ſulphuric acid, the whole of the muriatic acid gas that could be obtained by a moderate heat from theſe materials was tranſmitted into the oil of turpentine, and wholly abſorbed by it. In conſequence of this the oil became exceedingly hot, and acquired firſt a light lemon colour, and towards the end of the proceſs a clear tranſparent brown, a ſmall quantity of a thick oily fluid being gradually diſengaged and ſinking to the bottom. The liquor being allowed to cool for twenty-four hours was found concreted into a ſoft cryſtalline maſs, from which, when laid on a ſloping ſurface the brown liquor drained away. Being then wrapped in filtering paper and ſubjected to moderate preſſure, twenty-four ounces of a perfectly white cryſtalline matter were left behind of a peculiar odour, in ſome degree participating both of oil of turpentine and muriatic acid. The liquor which had drained from the cryſtals was placed in a cool cellar, and in the ſpace of a few days was found to have depoſited four ounces more of cryſtals, and two ounces additional were obtained by expoſing it to a powerful freezing mixture. Thus four pounds of oil of turpentine yielded thirty ounces of cryſtals; or not far ſhort of half its weight.

The cryſtals of rough camphor thus obtained acquired a dazzling white colour by ſimply waſhing with water, but ſtill retained a terebinthinate odour; the waſhings were acidulous to the taſte, having taken up a little muriatic acid, and were highly aromatic. Another portion of cryſtals being waſhed with a weak ſolution of pearlaſh was found to reſemble common camphor in its odour, that of turpentine having nearly diſappeared. It was thought that ſublimation would be ſtill more effectual than waſhing in purifying this camphor, accordingly two portions of it were mixed, the one with an equal weight of charcoal, the other with quicklime, and were heated in glaſs alembics: the capitals ſoon became covered with radiating needle-ſhaped cryſtals of a brilliant white colour, entirely free from the terebinthinate odour, and

[e] An. de Chim. li. p. 270.

reſembling that of camphor, only not quite ſo powerful. In this ſtate it floats on the ſurface of water, and communicates to it a camphoric flavour; is very inflammable, ſoluble in alcohol, and precipitable from it by the addition of water. Nitric acid acts upon it in the ſame manner but more ſlowly than upon Eaſt Indian camphor; but it appears to be wholly inſoluble in acetic acid.

The preſence of camphor has been ſhown in ſuch a variety of ſubſtances, in all of which when brought to the higheſt degree of purification it appears to be abſolutely the ſame, that it may be conſidered as one of the ſecondary vegetable principles; and an accurate inveſtigation of its properties and compoſition becomes an enquiry of conſiderable intereſt.

Camphor on account of its volatility requires to be kept in well cloſed veſſels, it is not however by any means ſo eaſily evaporable as is generally ſuppoſed. According to Kunſemuller,[d] pulverized camphor ſpread thin, and expoſed to the air at a temperature not exceeding 52° Fah. does not loſe more than half its weight in 16 weeks; the ratio of volatilization however rapidly increaſes with an increaſe of temperature. The moiſture of the air alſo has a conſiderable effect, the loſs of camphor being much greater in a humid atmoſphere than in a dry one. The degree at which camphor melts is fixed by Venturi at 302° Fah. and, by dividing a maſs that has been cooled ſlowly in the direction of its laminæ, it appears to cryſtallize in octahedrons.

Water has little or no action on camphor; at a boiling heat however it takes up enough to acquire both the odour and flavour of this ſubſtance. By the aſſiſtance of gum-mucilage or ſugar, it forms with water a whitiſh emulſion.

Alcohol at the uſual temperature, will take up between a ſeventh and an eighth of its weight of camphor, and when boiling it will diſſolve half its weight, the greater part of which is again depoſited by cooling. If equal parts of camphorized alcohol and ſulphuric acid are diſtilled together, the produce is camphorized ether, and a tenacious black reſinous maſs remains in the retort.[e] Camphor is alſo copiouſly ſoluble in ſulphuric, and probably in all the other ethers. When camphorized alcohol or ether is mixed with water, nearly the whole of the camphor ſeparates in the form of curdy flakes, which being dried gradually, exhibit the camphor unaltered in any of its properties. Oils, both the expreſſed, the eſſential and the empyreumatic combine with camphor, as alſo do the reſins and balſams. The hardeſt and dryeſt reſins are converted by it into a ſoft tenacious maſs remarkably ſoluble in alcohol; it will even render copal conſiderably ſoluble in this fluid. The alkalies whether in their cauſtic or carbonated ſtate have no action whatever on camphor: nor will they unite even when digeſted with oil or ſoap.[f]

Sulphur and camphor will combine together by means of a very gentle fuſion: the reſulting maſs is brittle when cold, but ſoft and tenacious when warm. The alkaline ſulphurets will alſo unite by fuſion with camphor, and retain it when diſſolved in water: the addition of an acid throws down the ſulphur and camphor in intimate combination with each other.[g]

When ſet fire to in atmoſpheric air, and ſtill more in oxygen gas, camphor burns with a copious white flame and black ſmoke, and is entirely conſumed. A large quantity of carbonic acid is produced together with carburetted hydrogen. The ultimate conſtituent parts of camphor appear to be carbon, hydrogen, and oxygen, but in what proportions is not yet aſcertained.

Camphor when diſtilled *per ſe* riſes unaltered, but if mixed with bole in the proportion of four parts of the latter to one of the former, and ſubjected to dry diſtillation, it is converted to a butyraceous conſiſtence; and by a ſecond diſtillation with freſh bole is entirely reſolved into a fluid colourleſs oil, and a ſmall quantity of a watery acidulous liquor, ſmelling ſtrongly of camphor: the bole is at the ſame time reduced to a black ſparkling powder, being almoſt entirely deoxygenated. Clay, according to La Grange, produces the ſame effect. This oil of camphor, according to Koſegarten,[i] is nearly colourleſs, has a peculiar odour like that of thyme or roſemary, and bears a cloſe analogy to the eſſential oils. It is ſoluble in alcohol and ſeparable, unaltered, from its ſolution by agitation with water. It forms ſavonules with the alkalies. It is eaſily volatilizable by heat, but depoſits on the edges of the veſſel a white uninflammable cruſt which is ſoluble in water. Nitric acid produces no other effect on it than tinging it of a reddiſh colour; and even a mixture of concentrated ſulphuric acid and fuming nitric acid, only deepens its colour ſtill more, and brings it to a ſomewhat thicker conſiſtence.

Carbonic acid promotes in a remarkable degree the ſolubility of camphor in water.[k] For this purpoſe let finely pulverized or precipitated

[d] Journ de Phyſ. xxxv. p. 291. [e] Monnet in Journ. de Phyſ. v. p. 456. [f] Bindheim in Crell's neuſt. Entd. xi. p. 115.
[g] Dorfurt, abhandlungen uber den Camphor. [i] De Camphora. [k] Own Experiment.

camphor be mixed with water and put into the decanter-part of the apparatus, plate iii. fig. 47. then let carbonic acid be thrown in from the retort, and combined with the water by agitation, as long as any continues to be taken up; a highly carbonated water will thus be produced, in which a sufficient quantity of camphor is diffolved to make it both taſte and ſmell very powerfully of this ſubſtance.

Vinegar and muriatic acid will each of them by digeſtion take up a ſmall portion of camphor. The muriatic and fluoric acids, when in the ſtate of gas, diſſolve a conſiderable proportion of camphor, but depoſit nearly the whole by the contact of water. Concentrated ſulphuric acid diſſolves camphor largely even in the cold, but by the aſſiſtance of a moderate heat it takes up ſo much as to form a thick homogeneous maſs of a brown or black colour and a ſulphureous odour, which when warm is fluid, but coagulates by a moderate heat, and by evaporation is brought to a reſinous conſiſtence. This compound is ſoluble in alcohol, but is decompoſed by water: the camphor being diſengaged with little or no alteration, and the mixture now no longer exhaling a ſulphureous but a camphoric odour. The action of oxygen on camphorized ſulphuric acid is remarkable. If one part of camphor is diſſolved in eight parts of ſulphuric acid, and this liquor is poured in a retort upon four parts of black oxyd of manganeſe and as much water, the reſult of a ſlow diſtillation of theſe materials will be acetous acid mixed with a very ſmall portion of undecompoſed camphor.

Nitric acid when ſomewhat concentrated diſſolves camphor in conſiderable quantity at the uſual temperature. The ſolution is of a very dilute yellow colour, and ſeparates by ſtanding into two diſtinct liquids: the lower conſiſts of a mixture of nitric and camphoric acids; the upper fluid is of the conſiſtence of oil, and is called *acid oil of camphor*; it is a combination of camphor and nitric acid. This oil is ſoluble in alcohol, but is decompoſable with precipitation of the camphor by water or alkalies: the addition of oxymuriatic acid gas converts it at firſt to a roſe colour, and afterwards to a full yellow, and in all probability acidifies the camphor.

The converſion of camphor into a peculiar acid by repeated diſtillation with nitric acid was firſt obſerved by Koſegarten, and was afterwards more fully elucidated by La Grange.

The proceſs of Koſegarten is the following.[k] Put one part of camphor into a retort with 12 parts of ſtrong nitric acid, and diſtil it ſlowly to dryneſs; a large quantity of carbonic acid and nitrous gas is diſengaged, and the acid in the receiver is covered with a thin ſtratum of acid oil of camphor: a ſmall portion of the camphor ſublimes into the upper part of the retort, and the maſs at the bottom of the veſſel is camphor approaching to the ſtate of a vegetable oxyd. It has no longer the peculiar odour of the original ſubſtance, and when laid on a hot coal it evaporates with a ſomewhat reſinous odour, but without undergoing combuſtion: it is ſoluble in alcohol but not in water. This oxygenated camphor by being diſtilled twice to dryneſs with ten parts of nitric acid at each proceſs, is converted to a white pulverulent ſalt, ſoluble in hot water, and which has obtained the name of Camphoric acid.

The method of La Grange differs chiefly in requiring a ſmaller quantity of nitric acid.[l] He takes one part of camphor and four of nitric acid, and diſtils the mixture by a very gentle heat: the acid that paſſes over into the receiver, being mixed with four parts more of freſh acid, is returned upon the matter in the retort and again diſtilled. This is repeated five ſeveral times with 20 parts of nitric acid in the whole, and the operation is known to be finiſhed when the liquor in the retort cryſtallizes on cooling. The produce of camphoric acid by either of the methods does not much exceed one half of the camphor made uſe of.

Camphoric acid when cryſtallized haſtily appears as a maſs of white ſilvery filaments, but by ſlow cooling aſſumes the form of parallelipipedal or rhomboidal plates, which effloreſce on expoſure to the air. To the taſte it is ſlightly ſour and bitteriſh: it reddens ſyrup of violets and tincture of litmus. It diſſolves eaſily in alcohol and in hot water, but requires 200 parts of this fluid at the uſual temperature for its ſolution. When heated it gives out a thick aromatic ſmoak, and is entirely diſſipated: in cloſe veſſels it ſublimes unaltered if the heat is not too great. The alcoholic ſolution of this acid is not decompoſed by water, a circumſtance that diſtinguiſhes it from benzoic acid, to which it bears a conſiderable reſemblance. It is ſoluble in the expreſſed and eſſential oils and the mineral acids, and forms a precipitate with the muriat and ſulphat of iron.

Camphoric acid unites with the ſalifiable baſes forming a genus of ſalts, the Camphorats. Of theſe very little is known. The neutral and earthy camphorats, which are the only ones

[k] Gren, Handbuch. ii. p. 227. [l] Manuel, ii. p. 357.

that have as yet been the ſubject of any experiments, are all decompoſable by heat, except the camphorat of ammonia, which ſublimes unaltered. When expoſed to the flame of a blowpipe the acid burns off with a blue flame. The camphorats are decompoſable with abſtraction of the baſe by the mineral acids, and with abſtraction of the acid by moſt of the metallic, barytic, and calcareous ſalts. The camphorats of lime, barytes, and magneſia yield their acid to alcohol.

The uſe of camphor in the arts is to aſſiſt the ſolution of reſins in various menſtrua. It is employed with ſucceſs in cabinets of natural hiſtory to prevent the approach of inſects, which appear to be ſtupefied and killed by the pungency of its odour. But its principal uſe is as a medicine both externally and internally.

CAOUTCHOUC. *Elaſtic Gum.*

This ſingular vegetable ſubſtance was firſt brought to Europe from South America about the beginning of the laſt century. But nothing was known concerning its Natural hiſtory till in 1736 a memoir was preſented to the French Academy by Condamine, in which it is ſtated that there grows in the province of Eſmeraldas, in Braſil, a tree called by the natives Hhevé, from the bark of which there flows, on its being wounded, a milky juice, which by expoſure to the air is converted into caoutchouc. M. Freneau diſcovered the ſame tree in Cayenne, and tranſmitted an account of it to the Academy fifteen years after the firſt notice of it by Condamine. Later reſearches have proved that there are at leaſt two trees natives of South America from which caoutchouc is obtained, namely, the *Hœvea caoutchouc* and *Jatropha elaſtica*, and it is not improbable that it is yielded by other ſpecies of theſe genera. The American caoutchouc is generally brought to Europe in the form of globular narrow necked bottles like receivers, about an eighth of an inch thick, and capable of holding from half a pint to a quart or more. In its native country it is fabricated by the inhabitants into veſſels for containing water and other liquids; and on account of its ready inflammability is uſed in Cayenne as the chief material for torches.

A ſubſtance poſſeſſing all the properties of the American caoutchouc has alſo lately been procured by Mr. Howiſon, [a] ſurgeon in Prince of Wales's Iſland, in the Eaſt Indies, from the juice of a climbing plant, the *Urceola elaſtica*, a native of that ſmall iſland, and of the coaſt of Sumatra. The thickeſt and oldeſt ſtems of the urceola yield by far the largeſt proportion of caoutchouc. If one of theſe is cut into, a white juice ouzes out, of the conſiſtence of cream and ſlightly pungent to the taſte. When expoſed for a time to the action of the air, or more expeditiouſly by the addition of a few drops of any acid, a decompoſition takes place; the uniform thick cream-like juice ſeparates into a thin whitiſh liquor reſembling whey, and the caoutchouc concretes into a clot or curd covered ſuperficially with a thin coating of a butyraceous matter. If the juice as ſoon as collected is carefully excluded from the air, it may be preſerved for ſome weeks without any material change, but at length the caoutchouc ſeparates from the watery part in the ſame manner, though not ſo perfectly as it does by free expoſure to the air. The proportion of caoutchouc contained in the juice of the oldeſt ſtems is nearly equal to two-thirds of its weight; the juice from the younger trees is more fluid, and contains a conſiderably ſmaller proportion of this ſubſtance.

According to the experiments of Mr. Howiſon, cloth of all kinds may be made impenetrable to water by impregnating it with the freſh juice of the Urceola, and the pieces thus prepared are expeditiouſly and moſt effectually joined together by moiſtening the edges with either the entire juice or even the more watery part, and then bringing them in contact with each other. Boots, gloves, &c. made of this impervious cloth are preferable even to thoſe formed of pure caoutchouc, as they are more durable and retain their ſhape better. If a ſufficient quantity of this juice could be obtained, the important purpoſes to which it might be applied are almoſt innumerable.

The colour of freſh caoutchouc is yellowiſh white, but by expoſure to the air it becomes of a ſmoak-grey: American caoutchouc in the ſtate in which it is brought to Europe, being formed of a multitude of extremely thin layers, each of which is expoſed to the air for ſome time, in order to dry before the next is laid on, is of a yellowiſh ſmoak-grey colour throughout; but maſſes of Eaſt Indian caoutchouc being formed more expeditiouſly, are dark-coloured only on the outſide: when cut into they are of a very light brown, which however ſoon deepens by the action of the air. Caoutchouc is perfectly taſteleſs, and has little or no ſmell, except when it is warmed, it then gives out a faint peculiar odour. The elaſticity of this ſubſtance is very remarkable, and indeed is one of its moſt

[a] Aſiat. Reſearches, v. p. 157.

characteriſtic properties. Slips of caoutchouc when ſoftened by immerſion for a few minutes in boiling water may be drawn out to ſeven or eight times their original length, and will afterwards reſume very nearly their original dimenſions. During its extenſion a conſiderable quantity of caloric is given out,[b] which is very perceivable when the piece is held between the lips; and when it is allowed to contract a decreaſe of temperature will immediately take place. By ſucceſſive extenſions and contractions in the open air, and eſpecially in cold water, its elaſticity is much impaired and it refuſes to return to its former dimenſions; but when in this ſtate it is put into hot water it imbibes again the heat which it had loſt, and by degrees reſumes its original ſize. At the temperature of about 40°, caoutchouc begins to grow rigid, its colour becomes much lighter, and it is nearly opake; as the cold increaſes it becomes more ſtiff and harder, and in all probability by a pretty powerful freezing mixture would be made brittle. Theſe changes however depend merely on temperature, for a piece of hard frozen caoutchouc perfectly recovers its elaſticity by being warmed. The freſh cut ſurfaces of this ſubſtance will unite together by ſimple contact, and by a proper degree of preſſure may be brought ſo compleatly in union as to be no more liable to ſeparate in this part than in any other. Its ſpecific gravity, according to Briſſon, is 0.933. It undergoes no alteration by the action of the air at the common temperature. When boiled for a long time in water it communicates to this fluid a peculiar ſmell and flavour, and is ſo far ſoftened by it that two pieces thus treated and afterwards ſtrongly preſſed together will form a permanent adheſion to each other.

When heated at a temperature nearly equal to that of melting lead, caoutchouc runs into a black viſcid liquor of the conſiſtence of tar, which does not concrete on cooling, neither does it dry by long expoſure to the air. When held to a lighted candle it readily takes fire and burns with a copious white flame, and a large quantity of dark coloured ſmoak exhaling at the ſame time a peculiar but not unpleaſant odour: from its ſmoak a conſiderable proportion of fine lamp-black may be collected. In dry diſtillation it gives out ammonia and carburetted hydrogen.

Concentrated ſulphuric acid, eſpecially when heated, acts with conſiderable energy on caoutchouc, reducing it to a black, friable, charcoal-like ſubſtance, at the ſame time the acid itſelf is in part decompoſed, ſulphureous acid gas being extricated. When treated with nitric acid, azotic gas is diſengaged, mixed with carbonic and pruſſic acids; oxalic acid is left in ſolution, and the reſidue is converted to a yellow brittle maſs. By digeſtion in oxymuriatic acid the colour of caoutchouc is diſcharged; it becomes opake, is indurated and ſomewhat wrinkled, reſembling tanned leather; but appears to undergo no other change. Similar effects are produced, though more ſlowly by muriatic acid.

Ammoniacal gas, according to Dr. Thompſon, is abſorbed by caoutchouc, and forms a ſoft, glutinous and inelaſtic compound. The ſame able chemiſt alſo ſtates that the fixed alkalies are capable of combining with and diſſolving it: he has however omitted to mention the peculiar circumſtances required for effecting this. If ſlips of caoutchouc are boiled for a long time in cauſtic potaſh, they appear to be ſlightly hardened, but undergo no other change; when the alkali is evaporated almoſt to dryneſs, and the caoutchouc begins to ſoften by the heat, a combination begins to take place between the two, and an extremely fetid ſmell like that of animal putrefaction manifeſts itſelf. By repeatedly waſhing the maſs in hot water, its putrid ſmell is diminiſhed, though by no means got rid of; it is ſoft, ſlightly clammy to the feel, and conſiderably elaſtic when extended, it reſembles in its fibrous texture, its white colour and ſhining gloſſineſs, the tendons of animals.[c]

A ſomewhat ſimilar effect is produced by liquid ammonia. Some pieces of caoutchouc being macerated in exceedingly cauſtic ammonia for more than a year, exhibited on examination the following properties. Their colour was changed to a perfectly opake white, their bulk had not materially increaſed although a conſiderable quantity of liquid alkali might be ſqueezed out of them; their elaſticity was ſomewhat diminiſhed and they were ſlightly viſcid externally. On expoſure to a melting heat they crackled, ſhrivelled, and became contorted like pieces of animal fibre, and exhaled a faint odour, in which that of burning animal matter was evidently mixed with that which peculiarly belongs to caoutchouc. The inflammability was remarkably diminiſhed: a piece held in the flame of a candle crackled exceedingly, and was evaporated without combuſtion, except a ſmall portion that melted and blazed, and appeared to be the part which had eſcaped the action of the alkali.[d]

[b] Thompſon's Chemiſtry, iv. p. 355. [c] Own Experiments. [d] Ditto.

Caoutchouc is ſoluble with eaſe at a boiling heat in the expreſſed vegetable oils, in wax, butter, and animal oil, forming viſcid unelaſtic compounds.

Rectified oil of turpentine at the common temperature acts without difficulty on caoutchouc, firſt rendering it tranſparent and enlarging its bulk conſiderably, and in the courſe of two or three days effecting a compleat ſolution. The liquor is of the conſiſtence of drying oil, and when ſpread thin upon wood it forms a varniſh, which however is a long time in becoming dry. When mixed with wax and boiled linſeed oil, it compoſes an elaſtic varniſh, which is uſed in coating balloons.

The only menſtrua for this ſubſtance from which it can be again ſeparated unaltered are, ether, petroleum, and cajeput-oil.

The ſolubility of caoutchouc in ether was firſt diſcovered by Macquer, a circumſtance which, from its frequent failure in the hands of other chemiſts, was very generally called in queſtion till Cavallo cleared up the difficulty, by ſhowing the neceſſity of employing *waſhed* ether for this purpoſe. If freſh made ſulphuric ether is ſhaken in a vial with an equal quantity of pure water, the ſmall portion of acid which it generally contains is diſſolved out by the water, and the ether combines with about a tenth of its weight of this latter fluid. The waſhed ether is readily ſeparated from the reſidual water by decantation on account of its ſuperior lightneſs, and is now capable of effecting a compleat and ſpeedy ſolution of caoutchouc. The ſolution is of a light brown colour, and when ſaturated is conſiderably viſcid. A drop of it let fall into a cup of water immediately extends itſelf over the whole ſurface, and the ether being partly abſorbed by the water and partly evaporated, the water is found covered with an extremely thin film of caoutchouc, poſſeſſing its elaſticity and all its other characteriſtic properties. A ſimilar effect takes place when cloth of any kind is ſoaked in the ſolution, or any hard ſurface is ſmeared over with it; on expoſure to the air the ether is rapidly evaporated, and the caoutchouc which it was combined with is left behind. The affinity of this ſolution for caoutchouc is very great: if the edges of two pieces of caoutchouc are dipped in it and immediately brought in cloſe contact with each other, as ſoon as the ether is evaporated they will be found to be perfectly united.

There are two circumſtances which muſt always prevent the extenſive uſe of the etheric ſolution of caoutchouc, admirably qualified as it is in other reſpects for many uſeful purpoſes; theſe are, firſt, its expenſiveneſs, and ſecondly, the extraordinary rapidity with which the ether evaporates, thus rendering it impoſſible to lay an even coating of this varniſh on any ſurface, and clogging up the bruſhes by which it is applied. In order to form tubes or catheters of this ſubſtance, the beſt method is to cut a bottle of caoutchouc into a long ſingle ſlip, and ſoak it for half an hour or an hour in ether: by this means it will become ſoft and tenacious, and if wound dexterouſly in a ſpiral form on a mould, bringing the edges in contact with each other at every turn, and giving the whole a moderate and equal preſſure by binding it with a tape wound in the ſame direction as the caoutchouc, a very effectual union will be produced. After a day or two let the tape be taken off, and the cylinder of caoutchouc may be rendered ſtill more perfect by pouring a little of the etheric ſolution into a glaſs tube cloſed at one end, the diameter of which is a little larger than that of the cylinder of caoutchouc; which being introduced into the tube will force the ſolution to the top of the veſſel. Let the whole of the apparatus be then placed in boiling water, the ether will be evaporated, and a ſmooth and uniform coating of newly depoſited caoutchouc will remain upon the cylinder.

Petroleum when rectified by gentle diſtillation affords a colourleſs liquid not to be diſtinguiſhed from the pureſt naphtha; and this, according to Fabroni, has the property of diſſolving one-ſeventieth of its weight of caoutchouc, and of depoſiting it again unaltered, by ſpontaneous evaporation.[e] It does not appear however that this menſtruum has been much employed.

The ſolubility of caoutchouc in cajeput oil was firſt noticed by Dr. Roxburgh.[f] This is an eſſential oil procured in India from the leaves of the *Melaleuca Leucadendron*, and promiſes to be the moſt uſeful menſtruum of this ſubſtance that has hitherto been diſcovered. The ſolution is thick and very glutinous. When alcohol is added, this latter unites with the eſſential oil, "and leaves the caoutchouc floating on the "liquor in a ſoft ſemifluid ſtate, which on being "waſhed with the ſame liquor and expoſed to "the air, became as firm as before it was diſ-"ſolved, and retained its elaſtic powers per-"fectly, while in the intermediate ſtate between "ſemifluid and firm, it could be drawn out into "long tranſparent threads, reſembling in the "poliſh of their ſurface the fibres of the tendons

[e] An. de Chim. xii. p. 156.

[f] Aſiat. Reſearches, v. p. 167.

" of animals; when they broke the elaſticity " was ſo great that each end inſtantaneouſly " returned to its reſpective maſs. Through all " theſe ſtages the leaſt preſſure with the finger " and thumb united different portions as per- " fectly as if they had never been ſeparated, " and without any clammineſs or ſticking to the " fingers."

Alcohol has no action whatever on caoutchouc.

Although caoutchouc is procured in quantity only from the vegetable juices mentioned in the former part of this article, yet it appears to be contained in ſeveral other plants. It is contained in the milky juices of the Indian fig *(Ficus Indica)*, and of the bread-fruit tree *(Artocarpus incisa)*; the berries of the miſeltoe, and probably all the vegetable barks that yield bird-lime, abound with it. The caoutchouc however obtained from theſe ſources differs from that which we have been deſcribing in retaining a greater or leſs degree of viſcidity, and perhaps in other reſpects, for no accurate comparative experiments have yet been made to decide this point. An inveſtigation into the properties and compoſition of the birdlime from miſeltoe and holly-bark would in all probability lead to very intereſting reſults.

The uſes to which caoutchouc has hitherto been applied are the following. It is employed very extenſively for rubbing out black-lead pencil marks from paper, hence its uſual name of India rubber: it is of value to the chemiſt as a material for flexible tubes to gazometers and other apparatus: the ſurgeon is indebted to it for flexible catheters and ſyringes; and finally it enters as an eſſential ingredient into the compoſition of the beſt varniſh for balloons.

CAOUTCHOUC *Mineral.* See BITUMEN.

CAPITAL. An article of CHEMICAL APPARATUS. See Appendix.

CAPUT MORTUUM. *Tête morte*, Fr. *Todtenkopfe*, Germ.

This term is at preſent obſolete: it was uſed by the old chemiſts to expreſs the reſidues of diſtillations after all the volatile parts had been driven off by the action of heat. Theſe reſidues were at firſt thrown away as of no value. Glauber was the firſt who particularly employed himſelf in their examination, and was rewarded for his pains by the diſcovery of ſulphat of ſoda (Glauber's ſalt) in the caput mortuum remaining after the diſtillation of muriatic acid from common ſalt and green vitriol; and of ſulphat of potaſh (Sal ſecretum Glauberi) in the reſidue after the diſtillation of nitric acid from nitre and green vitriol.

CARBON. *Carbone*, Fr. *Kohlenſtoff*, Germ.

CHARCOAL. *Charbon*, Fr. *Kohle*, Germ.

Although carbon is an eſſential conſtituent part of almoſt all vegetable and animal ſubſtances, and is contained in vaſt abundance in the mineral kingdom, yet it is of very rare occurrence in a ſtate of abſolute purity. When uncombined with any other body it is cryſtallized, colourleſs, intenſely hard, and under its commercial and mineralogical name Diamond, is ranked at the head of the gems, and in proportion to its bulk is the moſt coſtly of all ſubſtances. The detail of its natural hiſtory and external characters will be given under the term DIAMOND, the chemical facts that have been diſcovered concerning it being all that we have to do with at preſent.

The firſt ſuggeſtion of the inflammable nature of diamond is due to Newton. This philoſopher having obſerved that inflammable bodies in proportion to their denſity poſſeſs a greater power of refracting the rays of light than other ſubſtances, was induced to rank the diamond among them on account of the eminent degree in which it poſſeſſed this property. This conjecture was verified in 1694 by the members of the Academy del Cimento at Florence, who conſumed ſeveral diamonds by placing them in the focus of a lens. Soon after Francis the firſt, emperor of Germany, contributed ſome diamonds which were conſumed by the heat of a furnace. Rouelle, Macquer, Cadet, and D'Arcet repeated the ſame experiments with conſiderable attention, and found that by expoſure to heat and air, diamond was not only evaporated, but actually burnt with flame; but that even a very high temperature when the air was excluded, produced no alteration in this ſubſtance.

In 1772, an experiment was made by Lavoiſier which may be conſidered as the firſt attempt to effect a chemical analyſis of diamond. He burnt a ſmall piece of this ſubſtance in a jar of atmoſpheric air by means of a powerful lens, and found that the original bulk of the air had been diminiſhed, and a quantity of carbonic acid was produced, whence he concluded that there exiſts a conſiderable analogy between charcoal and diamond. In 1785 Morveau diſcovered that diamond when dropped into melted nitre burns like charcoal, and without leaving any reſiduum. This fact ſuggeſted to Mr. Tennant a method of analyſing diamond which was effected in 1795 with complete ſucceſs.[a] The

[a] Phil. Tranſ. for 1797. p. 123.

apparatus made uſe of on this occaſion was a tube of gold cloſed at one end, and terminating at the other in a curved glaſs tube, ſo as to anſwer the purpoſe of a retort. By way of previous trial ſome purified nitre was heated in the tube till it became alkaline, and being then diſſolved out by water the ſolution was found to be abſolutely free from carbonic acid, as it did not affect the tranſparency of lime-water. Having thus ſatisfied himſelf with regard to the perfection of his apparatus, Mr. T. filled the tube with a quarter of an ounce of nitre and two grains and a half of ſmall diamonds: the gold tube was then heated to a full red, and kept at this temperature for an hour and a half. The gas diſengaged during the proceſs was aſcertained by the teſt of lime-water to contain only an extremely minute portion of carbonic acid. The alkaline reſidue of the nitre was then diſſolved out of the tube by water, and not the leaſt trace was found of the diamonds. The ſolution being mixed with muriat of lime a copious precipitate fell down, which being carefully collected was placed in a ſmall glaſs globe with a tube annexed: mercury was then poured in to fill it, and the apparatus was inverted in a baſon of the ſame fluid. Some muriatic acid was then introduced by which the calcareous precipitate was diſſolved, and the carbonic acid that it contained was at the ſame time diſengaged and collected in the annexed tube. The bulk of carbonic acid was ſomething more than 10.1 ounces of water, at 55° Fah. 29.8 Barom. A ſecond experiment was made in a ſimilar manner with one grain and a half of diamonds, and the carbonic acid obtained occupied the ſpace of 6.18 ounces of water, according to which proportion the bulk of the carbonic acid from 2.5 grs. of diamond would have been = 10.3 ounces. The carbonic acid thus diſengaged was again combined with lime, and by heating it in a cloſe tube with phoſphorus the carbonic acid was decompoſed, and its carbonaceous baſe which at the commencement of the experiment was diamond, aſſumed now the black colour and other characters of charcoal. The identity of charcoal and diamond is ſtill further confirmed by comparing the quantity of carbonic acid produced from the combuſtion of each. Lavoiſier, from ſeveral experiments which have been acquieſced in by all chemiſts as ſufficiently accurate, has ſhewn that 1 part of pure charcoal requires 2.5 parts of oxygen for its acidification; or that 100 parts of carbonic acid contain 28 charcoal and 72 oxygen. Now aſſuming the medium of Mr. Tennant's experiments as approaching very nearly to the truth, it follows that 2.5 grs. of diamond yield 10.2 ounce meaſures of carbonic acid at 55° temperature, and 29.8 barometrical preſſure. But 1 ounce meaſure is = 1.89 cub. inch, and 1 cub. inch of carbonic acid weighs 0.467 grain: therefore 2.5 grs. diamond yield 9.03 grs. of carbonic acid; and the correſpondence of this with the proportion of charcoal deduced from the experiments of Lavoiſier is manifeſt from the following equation,

: 100 carb. acid : 28 char. : : 9.03 carb. acid : 2.521 diamond

Since the publication of Mr. Tennant's paper the ſubject has been reſumed by Morveau at the Polytechnic ſchool at Paris, with no ſmall parade and pretenſions to accuracy; and as he has drawn from his experiments and calculations not only very different reſults from Mr. Tennant, but has made them the baſis of a new hypotheſis, it is requiſite to enter into their examination with ſome minuteneſs.

[b]A globular receiver of glaſs was filled with 11470 cubic centimetres (450 cub. inch.) of oxygen gas, and a diamond of the weight of 200 millegrammes (3.08 grs.) was placed within it: by the action of a powerful lens the diamond was conſumed and carbonic acid produced. A quantity of barytic water was then introduced, and a white precipitate of carbonated barytes was thrown down, weighing when dried at 212°. 192 centigrammes: now, as carbonated barytes according to Pelletier contains 22 per cent. of carbonic acid, theſe 192 centigrammes repreſent 42 centigrammes (6.48 grs.) carbonic acid. The gas remaining in the receiver amounted to 11242 centimetres, and ſtill contained carbonic acid, for on mixture with ammonia it experienced a diminution of ſomewhat more than 4 per cent. which gives 448 centimetres (8.21 grs.) more of carbonic acid. Hence it appears, that although 28 parts of charcoal and 72 of oxygen compoſe 100 parts of carbonic acid, yet the ſame quantity of carbonic acid requires only 17.88 diamond and 82.12 oxygen. M. Morveau therefore infers that diamond is pure carbon, and charcoal an oxyd of carbon, being compoſed of 63.85 carbon and 36.15 oxygen: this concluſion he conſiders as ſtrengthened by the experiments on plumbago by Scheele, who found that twice as much charcoal was requiſite to alkalize a given quantity of nitre, as of plumbago, and that 80 centigrammes of the ſame when diſtilled with 20 parts of nitre yielded 357 cubic centimetres of carbonic acid.

[b] An. de Chim. xxxi. p. 85.

The above are the principal facts and inferences contained in the memoir of M. Morveau, againſt which the following objections may be urged.

1. Allowing the author all his facts, there appears to be an eſſential error in his calculations. The carbonic acid as eſtimated by him from the carbonat of barytes produced is = 42 centigrammes, and the carbonic acid indicated in the reſidual gas by the teſt of ammonia, amounts to 448 centimetres more;

now 42 centigrammes = 6.48 grains
448 centimetres of carb. acid = 8.21

14.69 grains troy, being the total amount of carbonic acid. The quantity of diamond employed was = 200 millegrammes (3.08 grs. troy); therefore: 14.69 grs. carb. a. : 3.08 grs. diamond : : 100 : 20.9. Hence the proportions of diamond and oxygen in carbonic acid, inſtead of being as M. Morveau ſtates, 17.88 diamond and 82.12 oxygen, ought to be reckoned at 20.9 diamond and 79.1 oxygen. But there will be a ſtill nearer approximation to the proportions laid down by Mr. Tennant, if inſtead of eſtimating the carbonic acid from the carbonat of barytes and the quantity contained in the reſidual gas, we take as the baſis of our calculations the quantity of oxygen conſumed. Now this, according to Morveau, amounted to 677 centimetres, or 26.6 cubic inches; the weight of which, eſtimating the ſpecific gravity of oxygen at .0013562, is = 9.12 grs. troy, and this added to 3.08 grs. the weight of the diamond, reduces the quantity of carbonic acid to 12.2 grs. inſtead of 14.69 as deduced from the former method. Therefore 1 part diamond requires 2.96 oxygen to produce 3.96 carbonic acid: hence 100 parts carbonic acid are compoſed of

25 diamond
75 oxygen

100

which is not very different from Mr. Tennant's ſecond experiment, in which 1.5 gr. diamond yielded 6.18 ounce meaſures of carbonic acid, whence the proportions would be

27.4 diamond
72.6 oxygen

100.0 carbonic acid.

2. M. Morveau appears to have proceeded on erroneous grounds in his eſtimate of the carbonic acid contained in carbonat of barytes. M. Pelletier[c] ſtates the compoſient parts of the *native* carbonat of barytes at

22 carbonic acid
62 barytes
16 water

100

without, however, particularizing the experiments from which he obtained this reſult. But Klaproth from a ſeries of unexceptionable experiments[d] has clearly ſhown, that the native carbonat of barytes contains no water, and conſiſts of

22 carbonic acid
78 barytes

100

Now M. Morveau's carbonated barytes was *artificial*, and dried only at 212°, therefore it doubtleſs contained a conſiderable quantity of water; and 22 per cent. muſt be a greatly exaggerated ſtatement of its carbonic acid.

3. The experiments of Scheele which are brought to countenance theſe reſults are by no means ſufficiently accurate for the purpoſe: concerning the firſt, this able chemiſt ſimply ſtates, that "five parts of nitre are ſufficient to decompoſe one of charcoal; whereas ten parts of nitre are required to produce the ſame effect upon one part of plumbago."[e] Now, when it is conſidered that in theſe experiments the nitre and charcoal or plumbago were levigated together, and then projected into a red hot crucible, it will be obvious that the difference obſerved between the plumbago and charcoal is in a great meaſure owing to the ſuperior ſpecific gravity of the former, by which it was prevented from being thrown out during the detonation. With regard to Scheele's ſecond experiment, not to mention the imperfection of the apparatus, which conſiſted merely of a glaſs retort with a bladder faſtened to it; and that neither the temperature nor barometrical preſſure of the gas was noticed, nor the carbonic acid which remained in combination with the alkaline reſiduum of the nitre, — overlooking all theſe objections, and taking the proportions as ſtated by Morveau, they will be found if they prove any thing, to prove too much. 80 centigrammes of plumbago afforded, ſays M. Morveau, 357 cubic centimetres of carbonic acid; there-

[c] Memoirs de Chimie, ii p. 456. [d] Analyt. Eſſ. i. p. 223. [e] Eſſays, p. 247.

fore (reducing the whole to Engliſh meaſure) : 60.9 grs. carbon. acid : 12.3 grs. plumbago : : 100 : 20.1 ſo that a leſs proportion of plumbago is required for the formation of carbonic acid than even of diamond, and this without taking into account the 5 per cent. of iron contained in plumbago.

If theſe objections to the experiments of M. Morveau are well founded, we muſt return to the deductions of Mr. Tennant, and conſider charcoal and diamond as very nearly the ſame ſubſtance chemically ſpeaking, though differing ſo materially in many other reſpects; and as bearing to each other the ſame analogy as chalk to calcareous ſpar, alumine to ſapphire, ſilex to rock-cryſtal.

Diamond when placed in the focus of a powerful lens in contact with oxygen gas preſents the following phenomena. It firſt becomes of a clear red, and ſoon after is apparently enlarged in bulk by being ſurrounded by a faint white light, indicating it to be in a ſtate of combuſtion: minute black ſpots, having a leaden metallic luſtre occaſionally form on its ſurface, eſpecially when there is a ſlight remiſſion of the heat; the diamond gradually diminiſhes, and at length is entirely conſumed without leaving the ſmalleſt reſidue. It is ſomewhat remarkable, that although in a ſtate of actual ignition and ſurrounded with oxygen gas, it nevertheleſs immediately ceaſes to burn as ſoon as the focus of the lens is withdrawn. The beſt obſervations on the combuſtion of this ſingular ſubſtance by the heat of a furnace, are to be found in a valuable paper by Sir George Mackenzie.[f] A diamond being placed on a thin piece of baked clay, was introduced into a muffle previouſly heated red hot: it ſoon acquired the ſame redneſs as the muffle, and in a few ſeconds more became viſible by a bright glow. Being then removed from the fire it was found to have acquired a ſlight milky appearance, and its luſtre was impaired, but no black ſpecks were perceived on its ſurface. A diamond and a piece of plumbago were introduced together into a muffle; the latter was obſerved to exhibit the ſame luminous appearance as the former, only it began at a lower temperature. The air being excluded for a few minutes by cloſing the mouth of the muffle, both the diamond and plumbago loſt their brightneſs; but this ſoon returned on again allowing the air to circulate through the muffle, and was increaſed in both by blowing on them with a pair of bellows. The temperature required for the combuſtion of diamond is lower than has been generally ſuppoſed; Sir G. Mackenzie found that at 13° Wedgewood, the diamond had acquired the dim milky appearance juſt mentioned, and that the higheſt heat neceſſary for its compleat combuſtion did not exceed 15°.

In order ſtill further to aſcertain the identity of diamond and charcoal, it was ingeniouſly ſuggeſted by the French chemiſts to attempt to convert iron into ſteel by means of diamond inſtead of charcoal. This was ſucceſsfully performed by Clouet,[g] and afterwards repeated with ſome variations by Sir G. Mackenzie, in order to obviate certain objections that had been raiſed againſt the accuracy of the experiment.

The above are all the chemical facts hitherto known concerning diamond or carbon in its pureſt ſtate: we ſhall now proceed to treat of charcoal.

CHARCOAL.

The great conſumption of charcoal is as fuel, and the moſt uſual material of which it is prepared is wood. The moſt eſteemed kinds of wood for this purpoſe are oak, cheſnut, elm, beech, and aſh; the white woods and thoſe which abound in reſin being commonly rejected. Large timber, beſides being too valuable to be thus employed, furniſhes only a very inferior flaky kind of charcoal, the beſt being produced from coppice wood, the ſtems of which are from half an inch to two inches in diameter. Pieces three or four inches thick are not indeed rejected, but they require to be cloven in four previous to charring, which is ſome additional trouble, and the produce of charcoal is ſmaller in proportion than of the entire pieces. The wood when firſt cut down[h] is formed into large faggots, which are dried in the open air for two or three months, and are then in a fit ſtate to be made into charcoal. For this purpoſe it is ſorted into bruſh wood, the ſmaller ſtems, and the larger ones, the two latter of which are cut into truncheons from two to three feet in length. A ſquare or circular ſpace about fifteen feet in diameter is then marked out in a dry ſheltered ſpot, and the turf is carefully removed from its ſurface, which is beaten till it becomes quite hard, dry, and ſolid: a thick ſtake ſomewhat higher than the intended pile is driven into the centre of the area, and a thin ſtratum of bruſh wood is ſtrewed evenly over the whole ſpace ſerving as a foundation for the reſt. Above the bruſh-wood is laid a ſtratum of truncheons, taking care to place the thickeſt near the centre, and the thinneſt at the edges: over this

[f] Nicholſon's Journ. 4to. IV. p. 103. [g] An. Chim. xxxi. p. 328. [h] Arts et Metiers art. Charbonnier.

is ſpread a ſtratum of bruſh-wood, and ſo on alternately till the pile has acquired the heighth of about ſix feet, forming a truncated pyramid, or truncated cone. The top and ſides are now covered to the thickneſs of two inches more or leſs with dry earth, or the duſt remaining from a former burning; and over all is laid neatly a covering of ſods ſo as to exclude the air, except from the loweſt ſtratum of bruſh-wood, and here the ſods are laid with as great intervals between them as can be allowed conſiſtently with giving a firm ſupport to the upper ſods which reſt upon them. The pile being thus arranged one of the workmen mounts to the top of it, and withdraws the ſtake that was driven into the centre of the area, filling up the ſpace with dry chips, and laying a lighted ſtick on the top. The fire ſoon begins to ſpread downwards, and torrents of ſmoke pour forth from the interſtices between the lower ſods and from the chimney in the centre: after ſome time a light column of flame riſes out of the chimney which is immediately ſtifled by the application of a piece of turf laid lightly on, ſo as almoſt but not entirely to cloſe the vent. In an hour or two the fire will have made conſiderable progreſs, and occaſional exploſions will take place, from the copious diſengagement and ſudden combuſtion of carburetted hydrogen, on which occaſions all the vigilance of the workmen is required. The approach of an exploſion is indicated by a rumbling kind of noiſe within the pile which terminates in a loud burſt as if the whole maſs was torn in pieces; no material derangement however happens except that a ſmall part of the covering is thrown out of its place, the extent of the damage being indicated by the flame and ſmoke that burſt forth. Theſe orifices as ſoon as they appear muſt be carefully cloſed by a few ſpadefuls of dry earth. In twelve or fourteen hours the exploſions will have ceaſed, and the ſmoke will diminiſh; the workmen muſt now begin gradually to cloſe up the interſtices at the bottom of the pile, beginning on the windward ſide, and then for the next twenty hours no further attention will be required except to ſee that no accidents happen: the fire quietly ſpreads towards the circumference, which when it has reached the ſmoak almoſt entirely ceaſes, and the whole maſs appears glowing in every part. The wood is now thoroughly charred, and nothing more is neceſſary than to extinguiſh the fire: this is done by throwing on a quantity of dried earth ſufficient to cover the whole to the depth of a few inches, and taking care to ſtop up all cracks as ſoon as they appear. In the courſe of the fourth day from building the pile, the charcoal is generally fit to be removed, and this is aſcertained by making an opening into the maſs while yet warm, and if the fire is entirely extinguiſhed it is immediately taken to pieces, but if on expoſure to the air it begins to glow the opening is carefully covered, and the breaking up of the pile is deferred to the next day.

The above is the French method of preparing charcoal; but the mode followed in Scotland with the moſt ſucceſs differs ſo conſiderably from that juſt deſcribed, as to require particular mention. The French charcoal is chiefly calculated for culinary uſes, and is therefore made of conſiderably ſmaller wood than the Scottiſh, which is entirely employed in the iron works. [b] The proceſs begins by raiſing a plot of ground a little higher than the ſurrounding ſurface, and bringing it to a ſlightly convex form. In the centre of this area is placed a circle of ſticks, the looſe ends of which are directed inwards ſo as to croſs each other a few inches below the top, and thus form a kind of cup of the ſhape of an inverted cone. Round this interior circle are ranged ſucceſſive concentric circles, formed by truncheons from one to ten inches in diameter, care being taken that the truncheons in any one circle are of the ſame diameter, and that one built of the largeſt wood is always ſucceeded by another of the ſmalleſt wood, in order that there may be as few interſtices as poſſible. The outermoſt circle is compoſed of bruſh-wood. When the pile meaſures from twenty to thirty feet in diameter it is ſufficiently large. A coating is now laid on of turf, the graſſy ſide next to the wood, and dry earth is heaped up around the bottom of the pile, and well rammed down in order to prevent the admiſſion of air. The maſs is lighted in the centre, by dropping into the cup formed by the interior circle ſome dry lighted chips, and in proportion as theſe are conſumed other ſmall pieces are put in during the firſt four or five days. When the upper part of the pile is ſufficiently kindled, a row of holes, each about two inches in diameter is opened a few inches below. The hole at the top is then cloſed, and the fire now compleatly kindled ſlowly deſcends to the circle of air holes. As ſoon as it has reached this point, which is known by a remarkable diminution of the ſmoak and vapour; a ſecond row of holes is opened at the diſtance of ſix or eight inches below the firſt

[b] Muſhet in Phil. Mag. iii. p. 12.

which are closed up again. In this manner the fire is conducted to the bottom of the pile in the course of about a fortnight: at this period the pile is covered up as accurately as possible till the fire is compleatly extinguished. Those pieces that are found to be not sufficiently charred are called *brands*, and are employed as fuel for the next fire.

The charcoal produced from the truncheons is laid by itself, and sold under the name of charcoal; that from the brush-wood is disposed of at a lower rate, and is called in the London market *small coal*.

Although charcoal prepared by either of the above methods is fully adequate to all the purposes of fuel to which this substance is applied, yet in the manufacture of gunpowder, and for some other uses, it is of essential importance to procure a charcoal of greater purity than common. This was formerly done by selecting stems of willow, alder, and some other of the aquatic trees, and charring them in the usual manner, but with peculiar care. Of late, however, a very considerable improvement in the preparation of the finer charcoal has taken place by charring or distilling the wood in closed iron cylinders. For this purpose a large cylinder of cast iron fixed in masonry over a grate, and furnished at one end with a door capable of being accurately closed, and terminating at the other in a curved pipe, is filled with the chips or saw-dust of any kind of wood; the door being then closed and a fire lighted in the grate, the empyreumatic acid, and all the other volatile parts of the wood are driven off by the heat, which is increased till the contents of the cylinder are red hot. The fire is then withdrawn, the cylinder is allowed to cool, and a black shining and remarkably pure charcoal, in greater quantity also in proportion to the wood employed than by the usual way, is procured, admirably fitted for the use of the gunpowder makers, and apparently possessed of the same qualities from whatever kind of wood it is made.

The proportion of charcoal yielded by particular woods is liable to be so materially affected by the age, and the dryness of the wood and the method in which it is charred, as renders it almost impossible to obtain any correct results in the great way. The following table from experiments in the small way by Mr. Mushet,[c] will however be found to be interesting, as all the woods before being charred, were thoroughly dried and prepared as nearly as possible in the same circumstances.

100 parts of lignum vitæ	afforded 26.8	of charcoal, of a greyish colour, resembling oak.
—— mahogany	—— 25.4	—— tinged with brown, spongy and firm.
—— laburnum	—— 24.5	—— velvet black, compact, very hard.
—— chesnut	—— 23.2	—— glossy black, compact, firm.
—— oak	—— 22.6	—— black, close, very firm.
—— American black beech	—— 21.4	—— fine black, compact, remarkably hard.
—— holly	—— 19.9	—— dull black, loose and bulky.
—— sycamore	—— 19.7	—— fine black, bulky, moderately firm.
—— walnut	—— 20.6	—— dull black, close, firm.
—— beech	—— 19.9	—— dull black, spungy, firm.
—— American maple	—— 19.9	—— ditto.
—— Norway pine	—— 19.2	—— shining black, bulky, very soft.
—— elm	—— 19.5	—— fine black, moderately firm.
—— fallow	—— 18.4	—— velvet black, bulky, loose and soft.
—— ash	—— 17.9	—— shining black, spungy, firm.
—— birch	—— 17.4	—— velvet-black, bulky, firm.
—— Scottish pine	—— 16.4	—— tinged with brown, bulky, moderately firm.

Charcoal of wood, whatever care is taken in the burning to drive off all the volatile products, can never be entirely pure, as it must retain all the earthy and metallic ingredients of the wood, the proportions of which vary from $\frac{1}{50}$ to $\frac{1}{10}$ of the charcoal; for the more delicate operations of chemistry therefore, that species of charcoal is made use of which is procured from the combustion of oily or resinous substances, and is known in commerce by the general name of *Lamp-black*.

Lamp-black is prepared in large quantities by the turpentine manufacturers from the impure resin that remains after the distillation of oil of turpentine, and other refuse matters of the same kind. These are burnt in iron pots, or in a fur-

[c] Phil Mag. iii. p. 17.

nace appropriated for the purpoſe, and the denſe ſmoak ariſing from the combuſtion is introduced into chambers hung with ſacking, upon the ſurface of which the ſoot or lamp-black is depoſited, and whence it is ſwept off from time to time and ſold, without any further preparation. Common lamp-black is not indeed pure charcoal, being mingled with ſome empyreumatic acid and a portion of reſin in a ſtate of imperfect decompoſition, but after it has been heated to redneſs in a cloſe veſſel, all theſe impurities are driven off, and there remains behind a charcoal in a ſtate of almoſt perfect purity, as it burns away with hardly any perceptible reſidue.

Charcoal is an excellent conductor of electricity and Galvaniſm, but tranſmits caloric with very great difficulty: a very ſhort piece may be held by one end while it is heated red at the other, without conveying any notable warmth to the hand.

The combined action of air and moiſture at the uſual temperature upon this ſubſtance can ſcarcely be perceived, hence the advantage of charring the ſurface of ſtakes and piles that are driven into moiſt ground, it being found by long experience that theſe are much more ſlowly rotted than the ſoundeſt timber deprived of this covering.

Charcoal is infuſible by the greateſt heat that can be applied. When expoſed to a high temperature in dry and perfectly cloſe veſſels, it loſes little or nothing of its weight, but ſhrinks in ſize and becomes proportionably harder, denſer, more compact, and of a very deep velvet black colour. But although charcoal is thus unalterable by heat when the air is excluded, yet when made red hot and expoſed to the air, it readily undergoes combuſtion, and by uniting with oxygen is converted into a heavy gaſeous acid, formerly called *fixed air*, but in the reformed nomenclature known by the name of CARBONIC ACID.

Pure oxygen gas produces, as might be expected, a much more rapid effect on charcoal than atmoſpheric air does; a piece heated at one end to the loweſt ſtate of redneſs, and plunged in this gas, immediately burns with an intenſely white glow, unaccompanied by flame, and is ſpeedily changed into carbonic acid. Twenty-eight parts of charcoal and ſeventy-two of oxygen, according to the experiments of Lavoiſier, form 100 of carbonic acid.

Water is very obſtinately retained by charcoal, partly on account of its porous texture, and in part probably on account of a ſtrong mutual affinity, but no ſolution of one in the other takes place even at a boiling heat: when however charcoal is red hot, or nearly ſo, it decompoſes any water with which it may happen to be in contact, and unites with both the elements of this ſubſtance, producing with the oxygenous baſe, according as this is added to ſaturation or not, carbonic acid and *gaſeous oxyd of* CARBON; and with the hydrogenous baſe a heavy inflammable air, CARBURETTED HYDROGEN. Common charcoal always contains more or leſs of moiſture, and it is to the decompoſition of this and the formation of the above-mentioned gaſſes, that the blue flame is to be attributed which makes its appearance when charcoal is calcined in a cloſe crucible; the ceſſation of the flame being a proof that nearly all the moiſture is expelled.

Various gaſſes ſeem to be abſorbed with ſingular facility by charcoal. This fact had been obſerved by Fontana, Prieſtley, Scheele, Morveau, and Morozzo, but it is to the Dutch chemiſts Rouppe and Van Noorden that we are indebted for a moſt intereſting ſeries of new and accurate experiments on this intereſting ſubject. It is abſolutely neceſſary that the charcoal made uſe of in theſe reſearches ſhould be entirely free from air and water, and two methods have been adopted ſucceſsfully to ſecure this point. The one is to heat a piece of charcoal till it is incandeſcent, and then to remove it from the fire as quickly as poſſible, and extinguiſh it in mercury previouſly dried, taking care to keep it in this ſituation for an hour or more, that it may be compleatly cooled. The gas to be operated upon is then to be introduced into a glaſs jar over mercury, and the charcoal being ſtill covered by the mercury is brought beneath the mouth of the inverted jar, into which on being let go it immediately riſes, and thus comes in contact with the gas. The ſecond method differs from the firſt merely in the manner of extinguiſhing the charcoal, by incloſing it while hot in an air tight copper box. This latter mode was that chiefly employed by Meſſrs. Rouppe and Van Noorden.[a] Theſe philoſophers found that one part of charcoal abſorbed in four or five hours three times its bulk of atmoſpheric air; that oxygen gas was abſorbed, at firſt rapidly and then more ſlowly, in the ratio of 2.8 times its bulk; azot was taken up only in the proportion of 1.6, and hydrogen of 1.8, but in both theſe caſes the abſorption was inſtantaneous. Of nitrous gas 8.5 parts were ſlowly, and of carbonic acid 14.3 parts were very rapidly abſorbed.

[a] An. de Chim. xxxii. p. 3.

The gaſſes thus taken up underwent no change except of form; the reſidues were unaltered, and the pieces of charcoal gave out the whole of the reſpective gaſſes with which they had been ſaturated on expoſure to the heat of boiling water. The abſorptions were effected at a temperature between 48° and 64° Fahr. and from repeated experiments it appeared that in a greater degree of cold a larger proportion of the gaſſes would have been taken up. If charcoal ſaturated with hydrogen in the manner above mentioned is introduced into oxygen gas, or even atmoſpheric air, a conſiderable abſorption of the oxygen takes place and combines with the hydrogen, forming water: at the ſame time a quantity of caloric is given out ſufficient to raiſe the thermometer from 52° to 100°. The reſult is the ſame if the experiment is inverted, that is if charcoal charged with oxygen is introduced into hydrogen gas. Charcoal ſaturated with hydrogen is capable even of decompoſing nitrous gas, abſorbing the whole of its oxygen and leaving behind only azotic gas. Charcoal ſaturated with azot decompoſes atmoſpheric air, abſorbing the whole of its oxygen, but has no action on hydrogen.

Charcoal is capable of entering into permanent combination with ſeveral combuſtible bodies. Its union with hydrogen will be treated of under the article CARBURETTED HYDROGEN.

The diſcovery of carburetted ſulphur is due to Clement and Deſormes,[e] and is thus prepared. Fill an earthen-ware tube with ſmall pieces and powder of newly burnt charcoal, fix it in a ſlanting direction in a furnace, and lute to the lower end a glaſs tube dipping into ſome water contained in a receiver. Faſten a glaſs tube alſo to the upper extremity of the earthen pipe, and fill it with ſhort cylindrical pieces of ſulphur, and fit a cork to the open end of the glaſs tube with a movable wire paſſing through its centre, by which the pieces of ſulphur may be puſhed at pleaſure towards the earthen pipe. The apparatus being completed, light the furnace and heat the pipe very gradually: the gas contained in the charcoal will ſoon be given out, and as ſoon as it ceaſes cauſe the ſulphur by means of the wire to approach the heated part of the apparatus. Allow it to remain at ſuch a diſtance that it may melt as ſlowly as poſſible and trickle down among the charcoal; for if ſuddenly heated it will become paſty and materially impede the ſucceſs of the experiment. If theſe precautions are duly obſerved, a yellowiſh oily liquid will ſoon be obſerved in the terminating glaſs tube, which will drop into the water of the receiver and collect at the bottom of the veſſel, without at all uniting with the ſupernatant fluid. The carburet of ſulphur thus obtained is a tranſparent liquid, colourleſs when pure, but generally of a yellowiſh green tinge, and of a diſagreeable ſlightly pungent odour, differing entirely however from that of ſulphuretted hydrogen. Very pure carburetted ſulphur may alſo be procured by diſtilling together at a high heat the ſulphurets of antimony or mercury with charcoal; but the ſame proceſs was tried ineffectually with iron and copper pyrites. The ſpecific gravity of carburetted ſulphur, though liable to ſome variations, may be ſtated at 1.3. It evaporates in the air with nearly the ſame rapidity as ether, and like this fluid ſinks the thermometer during the proceſs in a moſt remarkable degree. If a bell glaſs full of water is inverted in a baſon, and a little of this liquid is introduced, and the whole is then placed within the receiver of an air-pump, as ſoon as the atmoſpheric preſſure is reduced to about 9 inches of mercury, the carburet of ſulphur will begin to aſſume the gaſeous ſtate, will riſe in large bubbles to the top of the bell glaſs, without mixing with the water, which it will expel, and will again be reduced inſtantaneouſly and totally to the liquid ſtate upon reſtoring the atmoſpheric preſſure. Upon the application of flame, carburetted ſulphur takes fire and burns like other inflammable liquors, it gives out a ſulphureous odour and depoſits both ſulphur and charcoal. When kept in a cloſed veſſel along with atmoſpheric or azotic gaſſes, it is diſſolved by them in ſmall proportion, and renders them inflammable. It combines with nitrous gas, and the mixture burns with uncommon brilliancy, like zinc. It is taken up alſo by oxygen gas, and produces a detonating compound that explodes with prodigiouſly greater violence than the mixture of oxygen and hydrogen, ſo as to make it a highly dangerous experiment when performed even with comparatively ſmall quantities. When in the ſtate of vapour it combines ſlowly with the cauſtic fixed alkalies, forming deep amber-coloured ſolutions. It unites with phoſphorus, without however modifying its inflammability: it takes up by digeſtion a little ſulphur, but has no action on charcoal. By alcohol it is reduced to a ſoft paſty conſiſtence. It diſſolves in cold olive oil very eaſily, depoſits a little charcoal, and then aſſumes a cryſtalline form: the ſame effect happens when ether is ſubſtituted for oil.

[e] An. de C. xlii. p. 134.

Carbon is ſaid by Prouſt to be capable of uniting with phoſphorus, but this from an experiment of Clement and Deſormes[f] appears to be a miſtake.

Two of the metals are known to unite with charcoal: when in combination with IRON it forms *ſteel*, and with COPPER it forms a peculiar ſubſtance, firſt noticed by Dr. Prieſtley, and named by him *charcoal of copper*.

The action of the alkalies upon charcoal has not yet been examined into with any accuracy. Cauſtic potaſh when digeſted for ſome time upon charcoal becomes partly carbonated, but the carbonic acid thus produced is in all probability to be attributed to the decompoſition of a portion of water.

The undecompoſable acids appear to have no action on charcoal; but the decompoſable ones are deprived by it of their oxygen either in whole or in part, and the charcoal is converted into carbonic acid. Thus ſulphuric acid by being paſſed through red-hot charcoal furniſhes ſulphur, ſulphureous acid and carbonic acid. Nitric acid yields nitrous gas and carbonic acid; phoſphoric acid yields phoſphorus and carbonic acid. If charcoal highly dried and finely pulverized is ſhaken into oxymuriatic acid gas, it becomes immediately red hot, and falls as a ſhower of fire to the bottom of the veſſel.

No affinity has been indicated between charcoal and any of the earths.

Of the neutral and earthy ſalts thoſe with decompoſable acids are ſtrikingly altered by the action of charcoal at a red heat; the others ſuffer no material change. It is worthy of notice, that the decompoſition which the acids undergo in theſe circumſtances is much more compleat, owing to their fixity, than when they are ſubjected alone to the action of charcoal. Thus the ſulphats are changed not into ſulphites but into ſulphurets, and the nitrats give out not nitrous gas, but azot. It is remarkable however that phoſphat of lime is undecompoſable by charcoal. The metallic ſalts are all of them decompoſed by charcoal at a greater or leſs degree of heat in conſequence of the metallic baſe being deoxygenated, independently of the action of this ſubſtance on their acids. Some of the moſt eaſily decompoſable ſalts, as muriat of gold and nitrat of ſilver, when perfectly ſaturated may be decompoſed in the moiſt way at a boiling heat, or by help of the ſolar light at the uſual temperature by means of charcoal, the metal being depoſited on the ſurface of the charcoal with all its characteriſtic brilliancy and colour.

The effects of charcoal in clarification are both curious and important. They were firſt noticed by M. Lowitz of Peterſburg, and have been for the moſt part amply confirmed by ſucceeding obſervers. In order to be employed this way with the greateſt ſucceſs, it is eſſential that the charcoal ſhould be finely pulverized and very dry. For this purpoſe let ſome well-burnt common charcoal be rubbed in a mortar (with a few drops of water to prevent the duſt from flying about) and afterwards paſſed through a fine ſieve: fill a crucible with this powder, and lute on a pierced cover. When the veſſel begins to be red hot a light blue flame will iſſue from the hole in the cover: the heat is to be continued, gradually increaſing it for a few minutes after the flame has ceaſed: being then withdrawn from the fire, and placed in a dry ſituation till it is ſufficiently cool to be handled, it muſt be quickly opened, and its contents transferred without loſs of time into a perfectly dry well ſtopped bottle, in which the charcoal may be kept for any length of time without injury. The properties of this powder are very ſtriking. Being mixed with common vinegar, or any kind of wine, a thick froth riſes to the ſurface, and the liquors after filtration are found to be quite clear and entirely colourleſs. The filthieſt and moſt putrid ditch water is in like manner rendered perfectly limpid, inodorous, and inſipid, and rancid oils are deprived of their ſmell and taſte by repeated filtration through a ſtratum of this prepared charcoal. Hence alſo its peculiar efficacy as a dentrifice, its particles are ſufficiently hard to remove the concretions from the teeth without injuring the enamel, while it neutralizes and entirely deſtroys the fœtor with which the breath is not unfrequently tainted from a carious tooth.

The affinity of charcoal for oxygen is ſo conſiderable, that inſtances have been known of its undergoing ſpontaneous combuſtion by ſimple contact with the air. An occurrence of this kind took place at the powder-mills of Eſſonne in France.[g] A large quantity of recently burnt charcoal had been ground in the uſual manner, and was depoſited in a large receptacle for future uſe; ſome days after, the door of the magazine being opened in order to remove a part of the charcoal, an extraordinary heat was perceived, and immediately a train of fire was obſerved ſpreading over the ſurface of the char-

[f] An. de Chim. xlii. p. 149.

[g] An. de Chim. xxxvi. p. 93.

coal, which was not extinguiſhed without much difficulty.

The uſes of charcoal are very extenſive and important. Its greateſt conſumption is as an article of fuel both for domeſtic purpoſes and in the working of metals. It is of indiſpenſable neceſſity in the laboratory both as a fuel and an ingredient in all kinds of reducing fluxes. It is an eſſential conſtituent part of gunpowder, and is the baſis of almoſt all black paints and varniſhes. It is employed by mathematical inſtrument-makers and others in poliſhing braſs and copper, and is uſed in many caſes with great advantage as a ſimple and efficacious clarifier and purifier.

CARBONIC ACID.

CARBONIC ACID GAS. *Fixed Air. Aerial Acid. Mephitic Air. Kohlenſaure*, Ger. *Acide Carbonique*, Fr.

Carbonic acid is known to us only in its gaſeous ſtate when uncombined, and it is then the *fixed air* of Cavendiſh and Prieſtley, the *aerial acid* of Bergman, the *mephitic air* of other chemiſts. It was the firſt gas in which acid properties were clearly diſcovered, and many of its properties as a gas were known long before its exiſtence was ſuſpected in many of the compounds of which it forms a part. It is known to be an acid by the united characters of reddening vegetable blues, neutralizing alkalies and alkaline earths, and being formed by the union of a combuſtible baſe with oxygen.

Its alkaline, earthy, and metallic compounds are called *carbonats*, and will be deſcribed under that head; the properties of carbonic acid gas, and carbonic acid united with water, belong to the preſent article.

The ſources of this acid are immenſe, and widely diffuſed throughout the natural world. The chief are the following:

1. The atmoſphere always contains a ſmall portion, which ſeldom varies except in the immediate vicinity of places where reſpiration and combuſtion are going on in the large way, and is about one hundredth part. Hence it is that alkalies and lime loſe their cauſticity in the open air, by extracting its ſmall proportion of carbonic acid.

2. Many mineral waters riſe from the earth more or leſs ſtrongly impregnated with this acid, much of which flies off in the gaſeous form as ſoon as expoſed to the atmoſphere. The briſk frothing waters of Seltzer are examples of this kind.

3. Every proceſs in which coal, wood, or any other carbonaceous ſubſtance is conſumed, is one which generates this acid gas; and hence there is no vegetable matter on the face of the earth which does not give this acid largely when burnt.

4. The reſpiration of animals reſembles combuſtion in this reſpect, and hence there is a quantity of carbonic acid gas unceaſingly pouring into the atmoſphere from the lungs of every living animal.

5. The vegetation of plants is, under ſome circumſtances, a proceſs in which carbonic acid is generated, but is ſubject to more variations from external cauſes than reſpiration.

6. The ſpontaneous decompoſition of vegetable and animal matter alſo generates carbonic acid, more eſpecially the curious proceſs of vinous fermentation, from which many of the moſt important properties of this acid were firſt obſerved.

7. An immenſe ſtore of this acid is contained in the natural carbonats, more eſpecially all the varieties of lime-ſtone, chalk, and calcareous ſtones, many of which contain as much as 40 per cent. of their weight of this acid.

Other ſmaller ſources exiſt which do not require enumeration.

Carbonic acid gas, or fixed air, when procured by modes to be preſently mentioned, has the following properties. It is quite permanent at any temperature, nor can it, without combination, be exhibited by cold or preſſure in any other than a gaſeous form. It is abſolutely fatal to animal life, any living creature immerſed in it periſhing in as ſhort a time as it would by abſolute ſuffocation or interruption of reſpiration. Thus, ſmall animals, ſuch as mice, dropped into a veſſel of fixed air die almoſt immediately; dogs become convulſed and ſenſeleſs in about a minute, but recover in the open air if taken out very ſpeedily; men and large animals nearly the ſame, according to their powers of life; frogs and cold-blooded animals who have always in their lungs a ſupply of air for many minutes, live in it without much inconvenience till that internal ſupply is exhauſted, after which they periſh. Fixed air is incapable of maintaining combuſtion for a moment. If a lighted taper is let down into a jar full of this air, the taper is extinguiſhed as ſoon it reaches the level of the gas, as completely as if dipped into water. Even a ſmall admixture of this air with common air prevents combuſtion; for Mr. Cavendiſh found, that a candle dipped in a jar holding only one-ninth of fixed air went out immediately.[a]

Carbonic acid gas is the heavieſt of all the

[a] Phil. Tranſ. for 1766.

known gaſſes except the ſulphureous. Its weight compared to that of common air is very nearly as 3 to 2 in all circumſtances, hence its ſpecific gravity will be about .001806, and the weight of a cubic inch at 60° and 29.5 inches bar. will be about 0.456 grains. On account of its heavineſs, when generated, it falls rapidly to the ground, and ſpreads laterally over the ſurface, though after a time it mixes uniformly with the atmoſphere. This is well ſhewn at the Grotto del Cani, a cave in the vicinity of Veſuvius, through the floor of which a quantity of fixed air is conſtantly riſing from ſome ſubterranean reſervoir. A man ſtanding upright in it feels no inconvenience from the noxious gas, as it only riſes to about the height of his knee, but if a dog or other ſmall animal enters, it is preſently ſuffocated.

Carbonic acid gas is procured for experiment generally from limeſtone, chalk, marble, or any of the carbonats of lime, either by heat, or more commonly by any of the ſtronger acids. The diluted ſulphuric or muriatic are the acids moſtly employed. The latter is perhaps preferable, as the muriat of lime reſulting from the mixture remains diſſolved, whereas the ſulphat of lime from its little ſolubility cryſtallizes in the maſs, and ſomewhat impedes the proceſs. With ſmall pieces of marble, and moderately ſtrong muriatic acid, a conſtant and pretty uniform ſtream of gas is given out till the acid is ſaturated, or the whole of the marble diſſolved. Marble yields in this way from 40 to 45 per cent. of its weight of carbonic acid gas, ſo that 100 grains will yield between 90 and 100 cubic inches. The diſengagement of carbonic acid from any of the carbonats, whether alkaline, earthy, or metallic, is accompanied by a frothing or effervescence, occaſioned by the carbonic acid aſſuming the gaſeous form, or becoming carbonic acid *gas*, when detached from its combination by the affinity of the ſtronger acid to the baſe of the carbonat.

Heat is another method of obtaining the carbonic acid from the earthy carbonats. Chalk or marble encloſed in an earthen retort, and ſtrongly heated, readily gives out this gas: carbonat of magneſia with ſtill greater eaſe. The gas thus procured when united with water produces a leſs pungent liquid than that prepared by acids, ſo that probably the latter carries off with it a ſmall portion of the acid uſed, and therefore is not ſo pure.

All ſubſtances undergoing the vinous fermentation alſo give a copious ſupply of this gas, which from its weight long remains hovering over the ſurface of the fermenting maſs. Therefore ſubſtances placed in the vats of a brew-houſe juſt over the fermenting liquor, are thereby kept immerſed in an atmoſphere of carbonic acid gas, which however is not quite pure, being mixed with a ſenſible quantity of alcohol. *See* FERMENTATION.

Carbonic acid gas is readily abſorbed by water, and this combination is found in a very high degree in ſeveral of the moſt eſteemed *Mineral* WATERS. Carbonated water, when the proportion of carbonic acid is conſiderable, has a very agreeable, briſk, pungent taſte and ſmell, bubbles and froths ſtrongly when expoſed to the air, particularly when gently heated; and it is in this combination that the acid properties of carbonic acid are the moſt ſenſible, but when nearly at the freezing point the peculiar taſte is hardly perceptible, though cold water will abſorb more of the gas than warm.[b] This natural combination may be very well imitated by art, and ſince the firſt experiments of Bergman, Prieſtley, and Cavendiſh, many very ingenious contrivances have been invented to effect this combination in very large proportions; as the carbonated water in various modifications, has become a very faſhionable and ſalutary article for diet and medicine.

The abſorption of carbonic acid gas by water is ſhewn in the ſimpleſt manner by the following experiment: fill a phial quite full of cold water, invert it over a cupful of the ſame, and throw up a quantity of the gas from a bottle with a curved tube, in which marble duſt and muriatic or ſulphuric acid have been put. As the gas riſes into the inverted bottle the water is proportionally diſplaced, and when about half full of gas, ſtop the phial ſtrongly with the finger, and ſhake together violently the gas and the water. A ſtrong abſorption will immediately be felt by the external preſſure on the finger, and the water will be found ſenſibly to taſte of carbonic acid.

Agitation therefore is one method of aſſiſting the abſorption, and ſtrong preſſure is another equally powerful. Theſe are combined in a high degree in the forcing-pump apparatus uſed for preparing artificial mineral waters in the large way. The temperature alſo of the water much affects its abſorbing power; for Mr. Cavendiſh early in the enquiry found that cold water abſorbs much more than warm.

[b] Bergman.

Water at about 50° may by common means be made to take up nearly its own bulk of fixed air, but in the large way with a ſtrong forcing pump three times as much may be thrown in. Water thus highly carbonated muſt be incloſed in ſtrong bottles corked with particular precautions, and when the cork is drawn, the liquor froths and flies out like very briſk cyder.

Mr. W. Henry in his valuable experiments on the abſorption of gaſſes by water,[c] has ſhewn that the quantity of carbonic acid abſorbed under equal circumſtances of temperature, preſſure, and agitation, is alſo much regulated by the actual quantity of gas uſed, and by its purity, or in other words its proportion to the reſidual atmoſpherical air contained in the veſſels and in the water before the experiment, which no boiling nor expoſure in an exhauſted receiver can entirely ſeparate. Thus, if 20 meaſures of nearly pure carbonic acid gas be agitated with 10 meaſures of water at 55°, full 10 meaſures of the gas (or equal in bulk to the water) are abſorbed: but if the ſame quantity of water at 55° be agitated with a mixture of 20 meaſures of carbonic acid, and 10 of common air, only 6 meaſures will be taken up by the water. This is ſomewhat analagous to the obſervation of Dr. Brownrigg, that in carbonated water, however ſaturated, the gas will not eſcape when incloſed in an air-tight veſſel, with an empty and collapſed bladder communicating with it, though when expoſed to air the gas flies off readily. The diminution of abſorption in increaſed temperatures, Mr. Henry eſtimates to be about $\frac{1}{14}$ of the whole, for every 10 degrees above 55°. With regard to the effect of preſſure, Mr. H. deduces from experiments, the general law, that "under equal "circumſtances of temperature, water takes up "in all caſes the ſame volume of condenſed gas, "as of gas under ordinary preſſure." Therefore as the volume of all aeriform bodies is always inverſely as the compreſſing force, the quantity of gas abſorbed is directly as the preſſure to which it is expoſed; as, for example, if the common atmoſpherical preſſure, or that of about 30 inches of mercury, will cauſe the abſorption of carbonic acid equal in bulk to the water, a preſſure of two atmoſpheres muſt cauſe a double quantity to be abſorbed.

The ſpecific gravity of carbonated water containing its own bulk of carbonic acid, is about 1.0015.[d] It muſt be taken in a low temperature, otherwiſe the perpetual eſcape of the gas would defeat the accuracy of the experiment. By freezing, the water parts with the whole of its carbonic acid, juſt before it ſolidifies.

Water readily parts with its carbonic acid by being heated, and in this way it is collected in the analyſis of the carbonated mineral waters. To expel the whole it is requiſite to boil the water for ten or fifteen minutes.

The ſingle teſt of the acidity of carbonic acid by the change of vegetable colours, takes place with the infuſion of litmus, when added to carbonated water. When the water contains as much as $\frac{1}{16}$ of its bulk of this acid gas, it changes the blue of litmus to a red.[e] This is moſt conveniently ſhewn by diluting the litmus infuſion till it is of a very faint blue, putting ſome of it into a glaſs tube, and adding about as much of the carbonated water. If this is compared with an equal quantity of litmus liquor mixed with as much plain water in a ſimilar tube, the difference of colour will be very apparent. To ſhew that the redneſs is produced by the carbonic, and no other acid, let another portion be mixed with the carbonated water, previouſly boiled a few minutes to expel the acid gas, and no change of colour will now appear.

Lime-water is a much more delicate teſt of carbonic acid, either in its gaſeous ſtate or united with water, or even in combination with an alkali. In all theſe caſes, whenever lime-water comes in contact with carbonic acid, the lime eagerly abſorbs it, and becoming thereby inſoluble in mere water, it falls down in the form of a fine white precipitate, rendering the water milky, as when chalk is diffuſed in water. A very ſmall portion of carbonic acid will produce this effect, and hence it is that lime-water becomes cloudy and collects a white pellicle on the ſurface by mere expoſure to air, the atmoſphere containing on an average about one per cent. of carbonic acid. It is alſo very well ſhewn by blowing air from the mouth through any ſmall pipe dipping in a glaſs of lime-water. The breath contains about 5 or 6 per cent. of carbonic acid, which preſently renders the lime-water entirely turbid. When the acid is in ſolution the power of this teſt is equally great, diſcovering immediately, according to Bergman, about one cubic inch of the gas in 7000 grains of water, being $\frac{1}{14000}$ of the whole. It ſhould be obſerved however in uſing this teſt, that an exceſs of carbonic acid rediſſolves the firſt precipitate of carbonat of lime, ſo that there ſhould always be an exceſs of lime-water to engage all the carbonic acid it meets with. Thus if a very

[c] Phil. Tranſ. for 1803. [d] Bergman. [e] Ibid.

ſtrong carbonated water and lime-water be mixed together at intervals, the mixture will become turbid by the firſt portion of carbonated water, then by more of the ſame it will become quite tranſparent; then, a freſh portion of lime-water will again make it turbid; an exceſs of carbonated water will again rediſſolve the precipitate and make the liquor clear, and ſo on alternately.

Barytic-water and Strontian-water are equally good teſts with lime-water, and the two ſolutions holding more of the reſpective earths, they are more active in their operation.

When carbonic acid gas is contained in any gaſeous mixture, it is detected and readily abſorbed by the above-mentioned teſts, and the loſs which the whole gas experiences on being ſhaken with the teſt, indicates the quantity of carbonic acid contained. A ſolution of cauſtic or ſemi-cauſtic fixed alkali is a ſtill better ſubſtance to abſorb the carbonic acid gas, as it may be made ſo ſtrong that a very ſmall quantity of alkali will take up a large portion of the gas, and the full effect is immediately produced. With the alkali there is no cloudineſs or precipitate produced, ſo that the abſorption is the only teſt of the preſence of the acid gas.

It required the united efforts of many of the moſt eminent chemiſts to prove that the ſame ſubſtance which exiſts in a ſolid form in the hardeſt lime-ſtones, which gives the briſk taſte and ſparkling appearance to mineral waters, which is entangled in the froth of fermenting liquids, which is generated in the lungs of all living animals by reſpiration, and which performs a moſt important office in the functions of vegetable life, is the ſame that reſults from the combuſtion of charcoal and all carbonaceous matters, and therefore, according to the univerſally received theory of combuſtion, is compoſed of charcoal, the inflammable baſis, united to a portion of oxygen ſufficient to give it the properties of an acid. The full diſcovery and proof of this laſt fact is due to Lavoiſier, and from this elementary experiment he was able to deduce the exact compoſition of carbonic acid and the proportion of its conſtituent parts.

For this purpoſe he introduced ſome well-burnt charcoal into a large bell-glaſs filled with oxygen gas, having previouſly kindled a minute piece of tinder with an atom of phoſphorus adhering to it and in contact with the charcoal. As ſoon as the charcoal took fire, it began to burn in the gas with a very bright flame, throwing brilliant ſparks in every direction. The combuſtion ſtopped long before the whole of the oxygen was conſumed, owing to the carbonic acid generated, and mixing with it; and hence too there was very little diminution of the entire quantity of gas, as takes place in the combuſtion of phoſphorus, and many other bodies where the product is ſolid or liquid. When all was cold, the carbonic acid was ſubtracted from the reſidue by means of cauſtic alkali, the weight of which acid was very exactly equal to the united weights of the charcoal and the oxygen conſumed, and by computing the proportions of the two, it was found that carbonic acid is compoſed of about 28 of charcoal and 72 of oxygen. Subſequent experiments by different chemiſts agree very nearly in the above proportions. Thoſe of Clement and Deſormes,[f] made with picked charcoal heated ſtrongly for an hour in a covered crucible, and therefore in the pureſt poſſible ſtate, give 28.6 of charcoal to 71.4 of oxygen. No tinder nor phoſphorus were uſed to kindle it, for when any portion of the charcoal is heated red-hot in the air, the inſtant the oxygen gas reaches it, the combuſtion becomes brilliant, ſparkling, and rapid.

Carbonic acid is alſo produced by direct combination of carbon and oxygen when charcoal is diſtilled with the red oxyd of mercury;[g] which metallic ſubſtance diſtilled without addition, is known to yield a very large quantity of oxygen gas.

Carbonic acid is at its higheſt ſtate of oxygenation, and in any lower ſtate it loſes its acid properties. It is capable of decompoſition either wholly or partially, furniſhing many very curious experiments in each proceſs.

Phoſphorus is the only ſubſtance by which the carbonic acid has ever been compleatly decompoſed by compound affinity, and its baſe left in the ſtate of charcoal. This diſcovery is due to Mr. Tennant,[h] and was followed by other valuable experiments by Dr. Pearſon.

From the well known fact that the phoſphoric acid cannot be decompoſed by charcoal when united with lime (phoſphat of lime not yielding phoſphorus by diſtillation with charcoal) Mr. Tennant inferred that the united actions of phoſphorus and lime would be ſufficient to decompoſe the carbonic acid, and therefore that when carbonat of lime was heated with phoſphorus, the latter would abſorb oxygen from the carbonic acid, and be acidified at its expenſe. He accordingly put a little phoſphorus into a glaſs tube, cloſed at one end and coated with ſand and clay, and over the phoſphorus ſome powdered marble. The other end of the tube was

[f] An. Chem. tom. 39. [g] Prieſtley. [h] Phil. Tranſ. for 1791. [i] Phil. Tranſ. for 1792.

then closed up, leaving only a very small opening for the heated air to escape. After heating the tube red hot for a few minutes it was removed from the fire, and when cold, was broken. It contained a black powder, consisting of charcoal mixed with a compound of phosphat of lime or lime united with phosphoric acid, and of phosphuret of lime or lime with phosphorus. The phosphat of lime, and the lime of the phosphuret were separated from the charcoal by solution in an acid and filtration, the remaining phosphorus was expelled by sublimation in a close vessel, and thus the charcoal was left pure. This in no way differed from common charcoal of wood, deflagrating with nitre, and yielding carbonic acid by the combustion. In the above experiment therefore a part of the phosphorus is oxygenated at the expence of the carbonic acid, and the decomposition of the latter appears to be effected by complicated affinities, namely by that of a part of the phosphorus for the oxygen of the carbonic acid, of another part of the phosphorus for the lime of the marble, and of the phosphoric acid (as soon as formed) also for the lime. Therefore the experiment succeeds better if the marble is first slightly calcined, that the surface may afford caustic lime for the phosphorus immediately to act upon. Phosphorus alone has less affinity for oxygen than charcoal has, otherwise it could not be produced by the simple heating of a mixture of phosphoric acid and charcoal.

A similar decomposition of carbonic acid was effected by Dr. Pearson with phosphorus and carbonat of soda, dried so as to expel all its water of crystallization, but not its carbonic acid. After heating red-hot for twenty minutes, the contents of the tube, which were partly melted to the glass, consisted of some undecomposed carbonat of soda, of phosphat of soda, and of a black powder, which when separated and analysed was found by many satisfactory trials to be pure charcoal. The quantity of it varied in different experiments from 32 to above 40 grains, from 200 grains of phosphorus and 800 of dry carbonated soda of the first materials.

Besides this entire decomposition of carbonic acid, a partial deoxygenation takes place in a great variety of instances, and the product is that kind of inflammable gas, the nature of which was long unknown and confounded with hydrogen and with hydro-carbonat gas, till the late experiments of Mr. Cruikshank, who first pointed out the true grounds of distinction, and has demonstrated the leading properties of this substance, intermediate between carbon and carbonic acid, to which agreeably to the present system of nomenclature, the name of *Gaseous Oxyd of Carbon*, or *Carbonous Oxyd* has very properly been given. This will be described in the next article, and to it may be referred many curious experiments on the decomposition of carbonic acid by electricity, performed by Priestley and others.

Besides the sources of carbonic acid already mentioned, it is produced in abundance by the action of nitrous acid on charcoal, and even on any substance containing a carbonous base. Thus Dr. Priestley [k] procured it from alcohol and fuming nitrous acid. Under the article NITROUS *Acid*, it will be seen how far the action of this acid resembles the effects of common combustion, and hence it may generally be inferred that wherever carbonic acid would be generated by combustion, it would also be produced by the action of the nitrous acid on the combustible substance.

Many liquids absorb carbonic acid with great ease, such as alcohol, oil, &c. but it appears to be retained by no stronger adhesion than to water, and to be expelled by heat or other means, without having produced any sensible change. In like manner it mixes readily with every gas, but the only perceived effect is to render the air less able to maintain combustion (when at all so) and it does not seem to enter into any chemical union with any of the gasses. Ammoniacal gas must be excepted however, for with this it unites instantly, and a dense white cloud arises on mixture, which condenses into a solid *carbonat of ammonia*.

The affinity of carbonic acid with the alkalies, earths, and metals, is so weak that it is displaced in most instances by every other acid, the boracic perhaps excepted. Hence it is that a carbonated alkali will *effervesce* with any other acid, being expelled from the alkali in form of gas. This tendency to assume the gaseous form contributes much to the weakness of its affinity.

The order of the affinities of this acid are—barytes, strontian, lime, potash, soda, magnesia, and ammonia. With regard to the two last, their affinities are so nearly balanced that neither will entirely decompose the carbonat of the other substance, and the difference of a few degrees of temperature makes an essential alteration in the relative force of affinity.

The tendency of carbonic acid to quit all its combinations when strongly heated, renders it

[k] Obs. on Air, vol. i. 134.

impoſſible to aſcertain any of its affinities in the dry way.

CARBONOUS OXYD, or *Gaſeous Oxyd of Carbon.*

The diſcovery of the characteriſtic properties of this gas, and of thoſe chemical characters by which it is diſtinguiſhed from *carburetted hydrogen, hydrocarbonate,* or *heavy inflammable air,* is entirely due to Mr. Cruikſhank.

Till the reſearches of this chemiſt, it had always been objected by Dr. Prieſtley againſt Lavoiſier's hypotheſis of the conſtitution of fixed air (and always with a force of argument which only the wilfully blind theoriſt could overlook), that when charcoal, however dry, was diſtilled with ſcales of iron, or with the red oxyd of mercury, the product was not only carbonic acid, but a large quantity of a heavy inflammable air, which in ſome reſpects reſembled the true carburetted hydrogen obtained by diſtilling moiſtened charcoal in a red heat, and was miſtaken for it.

Carburetted hydrogen conſiſts of hydrogen holding ſome carbon in ſolution, and were it produced by charcoal mixed with any metallic oxyd, the preſence of the hydrogen could only be accounted for according to the antiphlogiſtic ſyſtem, by ſuppoſing ſome water to remain united with the charcoal and to be decompoſed during the diſtillation. But an inflammable gas is produced in great abundance, whatever be the heat to which the charcoal is previouſly expoſed, and therefore were it really compoſed of hydrogen, the objection to the whole hypotheſis founded on this experiment would be unanſwerable.

Dr. Prieſtley in the above inſtance ſuppoſed the water to be a conſtituent part of the iron ſcales, and to be ſeparated from it by the phlogiſton of the charcoal uniting with and reviving the iron, but it is rendered more than probable by Mr. Cruikſhank's diſcovery that water is not in the leaſt neceſſary in the one or the other caſe to the production of that kind of inflammable gas produced by the above method, that this gas neceſſarily contains no hydrogen whatever, but has only a ſingle combuſtible baſe, namely, carbon, and that with the ſame two ingredients as carbonic acid, it only differs from it in containing proportionally leſs oxygen, or in other words that it is an *oxyd of carbon.* Therefore it bears the ſame analogy to carbonic acid as the nitrous oxyd does to the nitric acid, the oxyd in each caſe not containing ſufficient oxygen to impart the properties of an acid.

The experiments of Mr. Cruikſhank[a] have been repeated with much apparent accuracy by Meſſrs. Deſormes and Clement,[b] and the reſults of the two correſpond very cloſely.

The gaſeous oxyd of carbon may be procured by ſeveral methods, that is, either by the partial oxygenation of charcoal by diſtillation with metallic oxyds; or by the partial diſoxygenation of carbonic acid by diſtilling the earthy carbonats with the filings of different metals; or by heating carbonic acid with charcoal, whereby the proportional quantity of the carbonous baſe is encreaſed; or by the decompoſition of carbonic acid by the electric ſpark.

Oxygenation of Charcoal by Metallic Oxyds.

The original experiment of Dr. Prieſtley is the following:[c] Equal parts of the ſcales of iron and charcoal (each having previouſly been made very hot in ſeparate veſſels) were put into a glazed earthen retort and ſtrongly heated. Inſtead of a product of *water,* which Dr. Prieſtley expected, a prodigious quantity of *air* came over, which on examination was found to conſiſt of only one-tenth of fixed air, and the remainder was *an inflammable air of a very remarkable kind, being quite as heavy as common air.* "The reaſon "of this," Dr. P. adds, "was very apparent "when it was decompoſed by dephlogiſticated "air, for the *greater part of it was fixed air.*" The above two important properties of this kind of inflammable air, namely, its weight, and its almoſt total convertibility into carbonic acid when ſaturated with oxygen, are fully confirmed by ſubſequent experiments.

Repeating this experiment of Dr. Prieſtley, Mr. Cruikſhank mixed ſome of the ſcales, or imperfect oxyd of iron ſeparated in forging, with powdered charcoal (each being previouſly heated for an hour to redneſs before mixture) put them into a coated glaſs retort and heated gradually, receiving the gas in the pneumatic ciſtern over water. As ſoon as the retort was red, abundance of gas came over, which being examined at different periods was found in the beginning of the proceſs to be compoſed of one part of carbonic acid and four of an inflammable gas (afterwards diſcovered to be the carbonous oxyd, with a ſmall admixture of carburetted hydrogen:) after which, to the end of the proceſs the proportion of the carbonous oxyd encreaſed to about ſix-ſevenths of the whole. Two ounces of the materials yielded many gallons of the gas.

The ſublimed oxyd of zinc was next ſubſtituted to the iron ſcales and diſtilled with charcoal. Even before the retort became red, much

[a] Phil. Journ. vol. v. 4to. [b] An. Chim. tom. 32. [c] Obſ. on Air, vol. i. p. 298.

gas was given out, and on encreasing the heat it came over in torrents. It contained a much less proportion of carbonic acid than the last, and towards the end it consisted of pure inflammable gas. The absence of carbonic acid was known by its not rendering lime-water turbid. Part of the zinc was found in the metallic state sublimed in the neck of the retort.

In like manner the red oxyd of copper and charcoal gave by distillation, first, a mixture of carbonic acid with inflammable gas, and at last a gas purely inflammable. The copper was found reduced in small globules. Litharge and charcoal gave a similar result, and the lead was reduced. The oxyd of manganese previously partially deoxidated by heating to redness, was also mixed with charcoal and distilled, and gave the same products.

The distillation of charcoal and the sublimed oxyd of zinc was repeated by Desormes and Clement, with particular attention to the quantity of products from a given weight of the materials. The charcoal and zinc were first heated separately and examined. Common charcoal heated strongly gave a considerable quantity of an inflammable gas, and about $\frac{1}{10}$ of its weight of water. After an hour nothing farther came over, so that to ensure the perfect purity of the charcoal, it should be used hot from a crucible or other vessel in which it has been heated to a full red heat for about an hour. The oxyd of zinc gave nothing at all by being heated *per se*, so that it may at any time be considered as pure when previously freed from accidental moisture.

By experiment it was found that 1436 parts of zinc increased by calcination to 1748 of white sublimed oxyd, and hence it is inferred that 100 parts of the white oxyd consist of 82.15 of metal, and 17.84 of oxygen. Thirty grammes (463 grs. troy) of pure charcoal prepared as above, and still hot, were mixed with as much oxyd of zinc (equal parts having been found to be the proportions in which the carbonous oxyd is given with more ease than when less charcoal is used) and were put into a coated glass retort, with an adopter communicating with lime water, through which all the gaseous products passed. When first heated, a small portion of carbonic acid appeared, rendering the lime water turbid, but this effect soon ceased, and the gas was purely inflammable. In five hours all the production of gas had entirely stopped, and the entire products of the operation were as follows:

	grammes
Zinc sublimed in the retort . .	21.82
Charcol remaining	26.60
Carbonic acid contained in the precipitated lime-water	0.07
Nine litres (16.9 wine pints) of inflammable gas, weighing	10.35
	58.84
Loss	1.16
	60.00

Dioxygenation of Carbonic acid.

Mr. Cruikshank having repeated an experiment of Priestley's to obtain an inflammable gas from carbonat of barytes, and the grey oxyd of iron, varied it in the following manner:

Equal parts of chalk (heated red hot previously for ten minutes) and iron filings were mixed and heated in a retort as before. Abundance of gas was given out, which consisted pretty uniformly of about one part of carbonic acid, and 5 parts of the inflammable gas.

An ounce of chalk, previously heated red for ten minutes, was mixed with as much zinc filings, and heated gradually in a coated glass retort. A little carbonic acid came over at first, but soon mixed with the carbonous oxyd, and when the contents were thoroughly red nothing but the inflammable gas came over, and in prodigious quantity. Examined at different periods of the distillation it was found perfectly inflammable, and free from carbonic acid. When cold, there was found in the neck of the retort some of the zinc sublimed and oxydated, below this some remaining metallic zinc, and at the bottom a crumbly mixture of unmetallic zinc with an imperfect lime.

Chalk with tin filings gave a similar result.

In the above three experiments the carbonic acid was united to an earthy base before distillation, and consequently it was exposed to the deoxydating effect of the metallic filings in its nascent state, or at the moment of its assuming the gaseous form, a state in which gaseous bodies are peculiarly susceptible of chemical change, frequently even when the very same substances refuse to act on each other after they have once acquired the state of gas. Mr. Cruikshank found however that even carbonic acid *gas* could be decomposed by the metals, though less perfectly. It was seen in the following way. A quantity of dry chalk was introduced into an iron retort, over which was rammed

ſome dry ſand, and a ſtratum of iron filings over all. In this arrangement therefore the carbonic acid gas expelled from the chalk by heat would have to traverſe a ſtratum of ſand three inches thick before it would reach the iron filings. The gaſeous products of the diſtillation were a quantity of undecompoſed carbonic acid, together with a large proportion of the inflammable gas, and the iron filings were found conſiderably oxidated when taken out. The decompoſition of carbonic acid by metals does therefore take place when the acid is in the gaſeous form, but by no means ſo perfectly as in its naſcent ſtate. A ſimilar decompoſition was alſo effected by forcing the ſame carbonic acid gas ſucceſſively backwards and forwards through an iron tube, the middle of which was full of iron filings, and was kept red hot by a ſmall furnace beneath it. A bladder was tied to each extremity of the tube to receive the gas. By twenty times paſſing the gas ſlowly through the red-hot part of the tube two-thirds of it were converted into inflammable gas, and, by continuing the proceſs, three-fourths.

Solution of Carbon in Carbonic Acid.

It is obvious that increaſing the oxidable baſe of any ſubſtance already united with oxygen muſt have the ſame relative effect, as abſtracting a portion of its oxygen; and this offers another mode of converting carbonic acid into the inflammable oxyd of carbon, which has been ſucceſsfully practiſed by Meſſrs. Deſormes and Clement.

Pelletier in his valuable experiments on barytes and ſtrontian,[a] diſcovered that the native carbonat of barytes, though ſcarcely calcinable *per ſe* in any fire, would readily part with its carbonic acid by calcination if previouſly rubbed to fine powder, and mixed with a ſmall quantity of charcoal. The chemiſts above-mentioned on repeating this experiment with three parts of carbonat of barytes and one of charcoal obtained a large quantity of gas, compoſed of about $\frac{4}{5}$ of carbonic oxyd, and $\frac{1}{5}$ of carbonic acid, and in the retort the barytes was left quite cauſtic. Here, therefore, it is to be ſuppoſed that the carbonic acid is ſuperſaturated with its own baſe, and thus rendered much more volatile than before.

A more direct combination of carbon with carbonic acid was alſo obtained by the ſame chemiſts, preciſely with the ſame apparatus which Mr. Cruikſhank had employed for paſſing the carbonic acid gas over red-hot iron, that is, with a tube filled in the middle with charcoal, and with a bladder faſtened to each extremity, which was kept alternately full or empty as the gas was preſſed backwards and forwards through the tube. The firſt ſenſible effect produced on the calcined gas was a conſiderable dilatation, which was excluſive of the expanſion by mere heat, and aroſe from the ſolution of a part of the heated charcoal in the gas as it paſſed over. After each experiment by far the greater part of the carbonic acid was found changed into the inflammable gaſeous oxyd of carbon, the proportions of the former varying from about $\frac{1}{10}$ to $\frac{3}{10}$. The remaining charcoal taken out and weighed was found to have loſt conſiderably, but the loſs was greater when iron tubes were uſed than with thoſe of glaſs or porcelain. Reckoning, therefore, the quantity of charcoal taken up by the carbonic acid in the different proceſſes to be indicated by the loſs of charcoal from the tubes, the compoſition of the gaſeous oxyd into which the carbonic acid was converted was found to be, when iron tubes were uſed, about 48 of oxygen to 52 of carbon; and when porcelain or earthen tubes were employed it conſiſted of about 53 of oxygen to 47 of carbon.

It would appear from the reſult of ſeveral experiments that the inflammable gas is the pureſt when prepared from chalk and iron, or zinc filings; for when charcoal and the metallic oxyds are employed, or charcoal in any way, ſome admixture of a gas always appears, which cauſes the production of a portion of water when the whole is burnt with oxygen, and therefore muſt be hydrogen; but this is not the caſe with the inflammable air from chalk or carbonat of barytes and metallic filings. This if taken after the firſt portions have paſſed over and waſhed with lime-water or cauſtic alkali, to ſeparate any carbonic acid it may contain, may be conſidered as pure *gaſeous oxyd of carbon*, or *carbonous oxyd*, and its characteriſtic properties, (according to Cruikſhank where not otherwiſe ſpcified) are the following, to which may be added the diſtinctive marks whereby it is found to differ from carburetted hydrogen.

Carbonous oxyd is nearly of the ſame ſpecific gravity as atmoſpheric air, being lighter than common air only in the proportion of 22 : to 23. Its ſpecific gravity therefore will be about 1.177 (water being 1000. and common air 1.2308). On the other hand, the average weight of the true carburetted hydrogen is not more than half that of common air.

[a] Memoires de Pelletier.

It ſuddenly deſtroys animal life. A bird put in a jar of it could not be withdrawn alive.[e]

It is no way altered by being electrized *per ſe* for a length of time.[f] In this it remarkably differs from carburetted hydrogen.

It burns in the open air with a quiet blue flame. When previouſly mixed with common air and kindled, it does not explode, but burns ſlowly; but mixed with oxygen it explodes by the electric ſpark, though not very violently. In this caſe the flame is red.

It is particularly by the products of combuſtion that this gas is diſtinguiſhed from hydrogen, or any other known ſubſtance. The product of the burning of hydrogen with oxygen is water, of carburetted hydrogen is carbonic acid and water in different proportions; but the combuſtion of pure carbonous oxyd produces nothing but carbonic acid, and in very large quantity. This is well ſhewn in two methods. In one, let a ſmall but conſtant jet of very pure gaſeous oxyd be ſet fire to, and immediately introduced in a large glaſs balloon full of oxygen gas (with the ſame apparatus as is deſcribed under the ſimilar combuſtion of hydrogen). It will then burn with increaſed brightneſs for a certain time, and be extinguiſhed ſpontaneouſly, but without ſo great a diminution of gas as might be expected, the ſides of the balloon will only be damp, but will not ſhew thoſe copious drops of water trickling down as appear when hydrogen is burnt, and the contents of the balloon will conſiſt altogether of carbonic acid gas, mixed with the unconſumed reſidue of oxygen. A ſecond mode of conducting the combuſtion, is to mix the gaſeous oxyd with oxygen in *Volta's Eudiometer*, and detonate the mixture by means of the electric ſpark. The exploſion is not ſo violent as with hydrogen, or eſpecially with ſome of the hydrocarbonates, and the reſidue is here alſo only carbonic acid together with any caſual impurity of the oxygen.

The relative proportions of carbonous oxyd and oxygen requiſite to mutual ſaturation, and the conſequent production of carbonic acid, are the means of aſcertaining the exact conſtituent parts of this inflammable gas. When 20 meaſures of the pureſt gaſeous oxyd (that is, from chalk and iron filings) were mixed with 8 meaſures of oxygen and exploded, the whole was reduced to 18 or 19 meaſures, the whole of which was abſorbed by lime-water, and was therefore carbonic acid. The weight of the latter alſo was found by other experiments to correſpond as nearly with the ſum of the weights of the two before mixture as can well be expected in experiments of this kind, for 100 cubic inches of carbonous oxyd with 40 inches of oxygen produced 92 cubic inches of carbonic acid, and the weight of the firſt of theſe may be eſtimated at about 30 grains, of the ſecond at 13.6, and of the third at 43.2 grains, and the ſum of the two firſt differs from the third only by .4 of a grain.

From the above data, confirmed by other experiments of Mr. Cruikſhank, it may be inferred that 100 parts *(by meaſure)* of gaſeous oxyd of carbon require for ſaturation 40 meaſures of oxygen gas and produce by combuſtion about 92 meaſures of carbonic acid gas: or *(by weight)* that 100 grains of carbonous oxyd require 45.$\frac{1}{2}$ grains of oxygen, and are converted into 144 grains of carbonic acid. As this acid is the only ſubſtance that appears after the combuſtion (ſuppoſing the trifling production of water to ariſe from accidental impurity,) and as carbonic acid is only compoſed of carbon and oxygen, it muſt follow that the inflammable gas muſt either be pure carbon, or carbon already mixed with a certain portion of oxygen, but not ſufficient for complete acidification. That the latter ſuppoſition is the truth is proved from a compariſon of the known proportions of carbon and oxygen in carbonic acid with the quantity of oxygen neceſſary to be added to the inflammable gas for complete acidification. Carbonic acid is found by Lavoiſier and other accurate chemiſts to be compoſed of about 28 (by weight) of carbon with 72 of oxygen; conſequently 144 grains of carbonic acid (the product of the full oxygenation of 100 grains of the inflammable gas) contain 42.32 grains of carbon; and hence, as only carbonic acid is produced by the combuſtion, the remainder of the 100 grains, or 59.68 grains muſt be oxygen. Or, by another calculation, 144 grains of carbonic acid contain 72 per cent. or 103.68 grains of oxygen; but only 45.33 grains of oxygen were added to the inflammable gas to produce this carbonic acid, and conſequently the difference between 103.68 and 45.33, or 58.35 grains of oxygen, were already contained in the gas, leaving 41.65 grains to complete the 100 grains of the gas, which is the carbon. So that the reſpective proportions of oxygen and carbon in 100 grains of the gaſeous oxyd is by one eſtimation 59.68 of oxygen to 40.32 of carbon, and by the other it is 58.35 to 41.65, the trifling difference between the two ariſing from the ſmall deficiency in the weight of the carbonic acid, compared to the ſum of

[e] Deſormes and Clement. [f] Ibid.

the weights of the gaſeous oxyd and of the oxygen conſumed in the combuſtion.

Therefore we may reckon on an average that 100 grains of the carbonous oxyd obtained from the decompoſition of the earthy carbonats with metallic ſubſtances in its pureſt poſſible ſtate, unmixed with any hydrogen, to be compoſed of about 59 of oxygen and 41 of carbon.

In this calculation it may be obſerved, the inferences from Mr. Cruikſhank's obſervations are corrected, by aſſuming more accurate proportions for the compoſition of carbonic acid, Mr. C. eſtimating only 20 per cent. of carbon in the acid, which is certainly much too low, as Lavoiſier's proportions have been amply confirmed by other chemiſts.

The experiments of Deſormes and Clement agree very cloſely with the above, theſe chemiſts deducing the compoſition of the gaſeous oxyd to be in 100 grains, 58.4 of oxygen and 41.6 of carbon.

All the above calculations ſuppoſe a perfect uniformity in the compoſition of the gaſeous oxyd, and the details of the various experiments will ſupport this opinion tolerably well, conſidering the great variety in the quantities of the accidental impurities of the gas, both of hydrogen and of carbonic acid, and of carburetted hydrogen, excepting in the ſingle inſtance of the carbonous oxyd produced by paſſing carbonic acid over red hot charcoal, where, as already mentioned, the quantity of carbon in the inflammable gas appears to be very variable, and to be much greater than when prepared in any other method. It is by no means improbable therefore that the carbonous oxyd may be ſuperſaturated with carbon, part of which may perhaps be again ſeparated by the action of affinities too weak to produce an entire decompoſition of the oxyd.

A true combuſtion of the gaſeous oxyd of carbon takes place when it is mixed with the oxymuriatic acid gas. If the latter be recently prepared and added to the carbonous gas in due proportion the whole mixture is converted into ſimple muriatic acid and carbonic acid, the oxygen having paſſed from the oxymuriatic acid to the carbonous oxyd and completed its acidification. Two meaſures of the carbonous oxyd were mixed with $2\frac{5}{8}$ meaſures[f] of the oxymuriatic gas in a bottle which the mixture completely filled, the ſtopper was put in, and the neck plunged under mercury. After twenty-four hours the ſtopper was taken out under water, which roſe immediately and occupied two-thirds of the bottle. This firſt abſorption was chiefly that of the muriatic acid. The reſiduum was then agitated with lime-water, and the whole was abſorbed except about $\frac{1}{6}$ of a meaſure, which was azot, and doubtleſs an accidental impurity.

The oxyd of carbon when heated in contact with phoſphorus diſſolves a portion, and then burns with a pale yellow. The phoſphorus is neither depoſited nor acidified by long ſtanding, or by being kept twenty-four hours over water.[g]

The effect of hydrogen upon the carbonous oxyd is very ſtriking. When equal parts of theſe gaſſes are mixed together and paſſed through a glaſs tube made red-hot,[h] a complete decompoſition takes place, the gaſeous oxyd depoſits its charcoal on the ſurface of the tube, which, being nearly melting, cauſes it to adhere and to form a very brilliant uniform black enamel, whilſt the oxygen of the gaſeous oxyd by union with the hydrogen forms water, which is condenſed at the further extremity of the tube. Some of the hydrogen paſſes through apparently unaltered.

The decompoſition of carbonic acid gas by electricity, when in contact with mercury, or ſome other metallic body, and alſo by hydrogen, well illuſtrates the nature of the carbonous oxyd. Dr. Prieſtley was the firſt who found a change to take place in carbonic acid gas by taking the electric ſpark in it repeatedly for a conſiderable time.[i] Out of many experiments the following may be ſelected: in a ſmall tube containing about $\frac{1}{15}$ of an ounce in meaſure filled with fixed air and ſtanding over mercury, the electric ſpark was taken for an hour; after which the whole tube was clouded chiefly with a black matter, but at the bottom with a yellow ſubſtance like ſulphur. Each of theſe ſubſtances was found to be part of the mercury by which the gas was confined and changed in the proceſs. The air itſelf was a little enlarged, but the great alteration produced in it was that inſtead of being all abſorbed by water, as pure fixed air is, about a fifth part remained inſoluble in this fluid.

This curious experiment was repeated by Monge[k] with great attention, and with ſimilar reſults with others of importance. He found that when the electric ſpark is taken in fixed air, the volume of the gas ſenſibly increaſes, and that this enlargement goes on for a conſiderable time though the electrization is ſuſpended: that it ceaſes after a certain time, and then the iron conductors (if this metal is uſed), are ſo completely

[f] Cruikſhank. [g] Deſormes and Clement. [h] Ibid. [k] Experiments on air, vol. i. p. 112.
[i] Mem. de l'Acad. for 1786.

oxidated as to let fall ſcales of oxyd from their ſurface, evidently ſhewing a connexion between the change of the gas and that of the metal. He alſo found that after electrization that part of the gas which was not abſorbed by cauſtic alkalies (and conſequently was not carbonic acid) was highly inflammable, and when mixed with oxygen it exploded by the electric ſpark, as pure hydrogen does. This made him conſider the reſiduary gas to be hydrogen, nor could the experiment be explained otherwiſe before the diſcovery of the gaſeous oxyd of carbon, which by ſubſequent experiments this is found to be.

The elegant experiments of Theodore de Sauſſure have thrown further light upon this ſubject.[1] Electric ſparks were taken for 18 hours in a glaſs tube containing 13 cubic inches of carbonic acid gas, pure and well dried, and confined by mercury. After electrization, much of the black oxyd of mercury deſcribed by Prieſtley was found, but the conductors, being copper, were not ſenſibly oxidated. A very ſlight dilatation amounting to no more than $\frac{1}{10}$ of a cubic inch was perceived. On throwing up cauſtic alkali only one cubic inch was abſorbed, which was therefore carbonic acid. The reſidue was not hydrogen, but very pure gaſeous oxyd of carbon; for when 100 parts of it were burnt with about one-third of oxygen gas no water was perceived, but the product was merely 77 parts of carbonic acid. No chemiſt has yet ſucceeded however in entirely converting carbonic acid into carbonous oxyd by electrization, but the quantity is obviouſly encreaſed in proportion to the continuance of the electric paſſage.

Carbonic acid gas was alſo found by the ſame ingenious chemiſt to be decompoſed by hydrogen with the aid of the electric ſpark. In a long glaſs tube, $3\frac{3}{4}$ parts (in bulk) of pure carbonic acid mixed with as much hydrogen were electrified for 12 hours. A condenſation took place, conſiderable at firſt, but towards the end, very ſlight. A number of fine drops of water were depoſited on the upper part of the tube, and when the proceſs was ſtopped, the bulk of the gaſeous mixture was reduced from $7\frac{1}{2}$ to $4\frac{3}{4}$ parts, 1 of which was undecompoſed carbonic acid, and the remaining $3\frac{3}{4}$ proved to be the gaſeous oxyd of carbon, being inflammable, unabſorbed by water or alkali, and when burned with a third of oxygen gas, giving carbonic acid in the proportion of 70 meaſures to 100 of the inflammable gas. It alſo contained a ſmall admixture of hydrogen. When the proceſs was finiſhed in a day the metallic conductors were not oxidated, nor the mercury altered.

In the above experiment the hydrogen appears to unite with part of the oxygen of the carbonic acid to form the water that is condenſed, whilſt the carbonic acid by loſing oxygen paſſes to the ſtate of carbonous oxyd.

It appears from an experiment of Deſormes and Clement[m] that hydrogen which has been ſhewn to be ſo powerful an agent in decompoſing both carbonic acid and carbonous oxyd, ſometimes effects a complete diſoxygenation of carbonic acid without ſenſibly paſſing into the intermediate ſtate of carbonous oxyd. Hydrogen gas paſſed through a tube, containing the native carbonat of barytes heated red hot, is found to render the barytes cauſtic or pure, and ſometimes to ſeparate the carbonic acid as ſuch, but at other times to bring over a quantity of a black carbonaceous powder, which is condenſed in the water of the recipient, and which theſe chemiſts ſuppoſe to be the carbon of the decompoſed carbonic acid.

A decompoſition of carbonic acid by hydrogen, ſimilar to that by electricity related by Sauſſure, alſo takes place when the mixed gaſſes are paſſed through a red-hot porcelain tube, and the gaſeous oxyd is produced.

CARBURETTED HYDROGEN GAS.

Hydrocarbonate, or *Heavy Inflammable Air*. *Gaz Hydrogène Carboné*, Fr. *Kohlenſtoffhaltiges Waſſerſtoffgas*, Germ.

The only definition that can apply to carburetted hydrogen as generally deſcribed, is, an inflammable gas conſiderably lighter than common air, not rendering lime-water turbid when ſhaken with it, and when burned with oxygen totally reſolvable into carbonic acid and water.

It ſhould be obſerved that many of the moſt important experiments on this gas were made previous to the diſcovery of the true nature of the carbonous oxyd, which diſcovery, whilſt it aſſiſts in the explanation of ſeveral difficult phenomena in chemiſtry, throws ſome uncertainty on the reſults of former enquiries into the properties of carburetted hydrogen, and renders a further examination highly neceſſary.

Before it was ſuſpected that carbon could exiſt in any other ſtate of oxygenation than as carbonic acid, it might be inferred with tolerable (though not abſolute) certainty that when any gas had been purified from carbonic acid by agitation with alkali or lime-water, if it furniſhed a freſh portion of carbonic acid after combuſtion with oxygen, the carbonous in-

[1] Jour. de Phyſ. tom. liv.

[m] An. Chim. tom. xliii. p. 288.

ingredient exiſted in the ſtate of pure carbon or charcoal. Therefore, as the only products of carburetted hydrogen when burnt with oxygen are carbonic acid and water, chemiſts generally ſatisfied themſelves with eſtimating the quantity of carbon contained in the gas by taking about 28 per cent of the weight of carbonic acid produced, and ſet down the entire remainder as hydrogen. For example, if 100 cubic inches of any gas weighing 15 grains, were totally reſolvable into carbonic acid and water by combuſtion with oxygen, and if by the combuſtion 54 cubic inches of carbonic acid weighing 25 grains were produced, the quantity of carbon originally contained in the gas would be reckoned to be 7 grains (being 28 per cent. of the weight of the carbonic acid) and the difference between 7 and 15, or 8 grains, would be conſidered as the weight of the hydrogen; or in other words the gas would be called a carburetted hydrogen, conſiſting of hydrogen holding carbon in ſolution, in the proportions of 8 (by weight) of the former, to 7 of the latter.

But it is obvious that this mode of eſtimating muſt be totally erroneous in the caſe (probably very frequent) of a mixture of gaſeous oxyd of carbon and hydrogen gas, and hence no approach to analyſis can be obtained without aſcertaining both the water and the carbonic acid produced, and even then ſome uncertainty will occur, as will be preſently mentioned.

So that it is poſſible, and by no means improbable, that there may exiſt three ſpecies of gaſſes, all of which have a claim to the title of *hydrocarbonat* or *carburetted hydrogen*, namely, 1ſt, hydrogen ſimply holding carbon in ſolution, or what correſponds with the original idea of a hydrocarbonat: 2nd. hydrogen mixed with gaſeous oxyd of carbon: 3d. a mixture of the two former ſpecies, or hydrogen gas and gaſeous oxyd of carbon, with an exceſs of carbon held in ſolution by one or both of theſe gaſſes. This laſt ſpecies therefore might alſo admit of ſome varieties, according to the ſolvent of the carbon.

Having noticed theſe difficulties, we proceed to the nature and properties of hydrocarbonat, as obſerved by different chemiſts.

Carburetted hydrogen gas is obtained in a great variety of ways, and with very conſiderable differences in ſpecific gravity and proportion of ingredients. It is found native on the ſurface of ſtagnant waters, marſhes, wet ditches, &c. through which, if examined cloſely, large bubbles will be ſeen to riſe in hot weather, and may be increaſed at pleaſure by ſtirring the bottom with a ſtick. In cloſe ſtill evenings if a candle is held over the ſurface, flaſhes of blue lambent flame may ſometimes be perceived ſpreading to a conſiderable diſtance. All that is not fabulous concerning the *ignis fatuus* is probably derived from this ſource. This ſpecies may be termed for diſtinction the carburetted hydrogen of marſhes. In the pureſt form in which it can be collected it is uſually mixed with about 20 per cent. of azot.

This gas is alſo given out very abundantly by almoſt every vegetable matter when ſubjected to a ſcorching heat ſufficient to decompoſe them. When heated in cloſe veſſels much more hydrocarbonat is obtained than when burnt in the open air, the product in the latter caſe containing more carbonic acid. It would be endleſs to enumerate the vegetable ſources of this gas, but ſome of the moſt convenient or uſual methods of obtaining it pure may be mentioned.

The deſtructive diſtillation of any of the acetous ſalts has often been uſed. For this, let any quantity of dry acetite of potaſh be put into a retort and heated gradually. The ſalt ſoon melts in its water of cryſtallization, puffs up, and would boil over if the neck were not kept very hot as well as the bottom. The firſt products are, the air of the veſſels and water, then when the acetous acid begins to be ſcorched, a large ſtream of gas begins and continues without interruption till the whole is fully red-hot, and little elſe remains in the retort but the alkali, in a carbonated ſtate. Along with the gas much oil ariſes at different times, and condenſes in the cool receiver. The gas, according to Dr. Higgins's very careful analyſis,[a] after the firſt portions have paſſed over, conſiſts of nothing but hydrocarbonat mixed with a variable portion of carbonic acid, which laſt may be ſeparated by lime-water. The hydrocarbonat itſelf varies conſiderably. The firſt part is much heavier than the laſt (though ſtill lighter than common air) and appears to hold in ſolution part of the oil, for on ſtanding ſome time over water it becomes lighter, and is found to require leſs oxygen for ſaturation than before. The average ſpecific gravity of the firſt and laſt gas mixed, which may be taken as an average of the whole, is to that of common air as 2 to 3.

Carburetted hydrogen is obtained in great purity by ſending the vapour of inflammable vegetable matter through an earthen or glaſs tube paſſing through a furnace and kept red-hot in the middle. The vapour of camphor, ether, alcohol, and other inflammables treated in this way is converted into this gas, but a very great

[a] Experiments on Acetous Acid, &c. London, 1786.

difference takes place in the quantity of the gas, according to the degree of heat and other circumſtances.

Another method of obtaining carburetted hydrogen is to put coal, wood, peat, &c. into any convenient veſſel, an earthen or iron retort for example, and heat it ſlowly to redneſs.

Moſt animal inflammable ſubſtances, ſuch as ſilk, fat, wax, and the like, yield this gas as freely as vegetable matters by a ſimilar treatment. This was diſcovered by Berthollet, in his moſt maſterly reſearches on the nature of animal matter and of ammonia; and as the gas in this caſe is not mixed with an unuſual portion of azot, he ſagaciouſly conjectured and afterwards fully proved that the azot, certainly contained in animal matters, went to conſtitute the ammonia which is always given off in the proceſs.

Carburetted hydrogen (or at leaſt a gas which gives carbonic acid and water by combuſtion with oxygen) is alſo generated in abundance when charcoal not previouſly dried is diſtilled *per ſe* in cloſe veſſels, and continues to be given off till it has been heated fully red-hot for about an hour, after which it ceaſes, and the charcoal, as mentioned under the two preceding articles, is now pure. A ſimilar, though ſomewhat different proceſs for obtaining the gas, is to encloſe powdered charcoal in a tube paſſing through a furnace, to confine the charcoal looſely by a pellet of clay at each end of the tube, to heat it red hot, and in that ſituation to ſend through it the vapour of water kept boiling in a ſmall retort attached to one end of the tube. Much carbonic acid gas is generated in this way, and when this is removed the remaining gas is inflammable.

Laſtly, this gas may be obtained by the direct union of its conſtituent parts. If hydrogen gas is paſſed ſeven or eight times ſucceſſively through an iron tube containing charcoal and heated red hot, a diminution of the bulk of the gas takes place, the hydrogen diſſolves a portion of the charcoal, and then aſſumes the properties of carburetted hydrogen. [b]

A moſt curious variety of hydrocarbonat gas was diſcovered by the aſſociated Dutch chemiſts (Van Dieman, Trooſtwyck, and others), which is procured from ether or alcohol, and has the remarkable property of generating or depoſiting a heavy oil when in contact with the oxymuriatic gas. Hence it has been termed *oily carburetted hydrogen*, or *olefiant gas*. It appears to conſiſt of carburetted hydrogen, ſuperſaturated with a large portion of carbonous matter in ſome unknown ſtate of combination, and hence it requires a much greater proportion of oxygen for ſaturation, and alſo produces a much larger quantity of carbonic acid than the other hydrocarbonats: it is alſo much heavier. The mode and preparation of this ſingular gas, and its peculiar properties, will be ſeparately deſcribed, but it may be added that according to Mr. W. Henry's experiments, [c] the olefiant gas appears to be alſo contained partially in the hydrocarbonat from coal, from wax, and ſome other ſubſtances, and greatly to contribute to the quantity of light and heat, which theſe gaſſes give out, as well as to the proportion of carbonic acid.

Hydrocarbonat gas is ſingularly affected by the electric ſpark. Dr. Auſtin [d] found that on taking the electric ſpark ſucceſſively through this gas obtained from the acetite of potaſh and in conſiderable purity, the bulk of the gas enlarged after every ſhock; and by continuing it from 200 to 300 times it expanded to nearly twice its original dimenſions. Examined after this expanſion it was found however to be as inflammable as before, and by the teſt of lime-water no carbonic acid was generated. Dr. A. concludes that the enlargement can be only owing to the production of a quantity of hydrogen, and makes ſome inferences from the experiments, the moſt important of which are ſhewn to be improbable by the ſubſequent experiments of Mr. Henry on the ſame ſubject. Mr. H. fully ſhews [e] that there is no *deſtruction* of carbon by this proceſs, ſince the ſame quantity of carbonic acid is produced by oxygen after electrization of the carburetted hydrogen as before it. He likewiſe makes it appear probable that the water held in ſolution by the gas is the chief agent in this expanſion, ſince when the gas is carefully dried by cauſtic alkali, no continuance of the electrization will enlarge it beyond one-ſixth of its bulk, but when the contact of water is admitted, it expands to double its bulk as before. Perhaps the diſcovery of the carbonous oxyd will explain this fact. It is not improbable that the carbon of the gas may unite with the oxygen of the water and produce the gaſeous carbonous oxyd, which would not give any precipitate with lime-water, and the bulk of the gas would be enlarged both by the carbonous oxyd and by the hydrogen of the water, and alſo by the expanſion which the hydrogen of the hydrocarbonat would undergo after the carbon was ſeparated from it: whilſt the actual quantity of carbon remaining the ſame, as much carbonic acid would be generated by compleat

[b] Deſormes & Clement. An. Ch. tom. 39. [c] Phil. Jour. 8vo. vol. ii. [d] Phil. Tranſ. vol. 80. [e] Ibid. vol. 87.

oxygenation as before electrization. It is not improbable that the affinities of carbon and hydrogen for oxygen are ſo nearly equal that either ſubſtance is able *partially* to decompoſe the compleat oxyd of the other. Thus we find (as mentioned in the laſt article) that when hydrogen and carbonic acid are together ſubjected to electricity, the carbonic acid is partially decompoſed, and the product is carbonous oxyd and water; and on the other hand when water is decompoſed by red-hot charcoal, a part of the product is alſo the carbonous oxyd.

The above expanſion of carburetted hydrogen by electricity Mr. Henry has ſhewn not to depend on any oxydation of the contiguous metals, ſince it takes place in a cloſe-ſtopped glaſs with conductors of gold, as well as with oxydable conductors, and over mercury.

All the hydrocarbonates are fatal to animal life, not merely (as appears) from its unfitneſs to ſupport life, but alſo from ſomething poſitively noxious, ſince animals immerſed in it die ſooner than they would from the mere interruption of reſpiration.

This gas is ſcarcely, if at all, abſorbed by water, but by long ſtanding over it, it loſes a portion of its combuſtible matter. This laſt however only applies to the hydrocarbonats that require at leaſt their own bulk of oxygen to ſaturate them, and eſpecially to that variety called the olefiant gas.

Simple carburetted hydrogen, when ſet fire to, burns at the ſurface in contact with the air with a blue flame with red edges, but when mixed with any of the olefiant gas the flame becomes much more brilliant, and reſembling that of oil. Applied to the purpoſes of illumination, the hydrocarbonat from coal, from lamp oil, or from wax, conveyed through an Argand's lamp produces full as much light as when ſupplied with oil in the uſual way,[f] and theſe are alſo the gaſſes that appear to contain olefiant gas, and an exceſs of carbonous matter relatively to their bulk. The brightneſs of the flame is much diminiſhed when theſe gaſſes have been long kept over water, and hence for illumination they ſhould be uſed as ſoon as prepared.

The combuſtion of carburetted hydrogen is much more brilliant in oxygen gas. If burnt in a veſſel of oxygen in the way that *hydrogen* is burnt for the production of water *(deſcribed under that article)*, the products may be collected, and are found to be ſimply carbonic acid and water.

If any of the hydrocarbonats is mixed with ſufficient oxygen gas, and fired by the electric ſpark, or any other method, an exploſion takes place more or leſs violent according to the quantity of carbonous matter condenſed in the hydrocarbonat; and the remaining gas conſiſts of carbonic acid, together with any unconſumed gas, or exceſs of oxygen, whilſt the water condenſes in drops on the ſides of the jar. A ſingle cubic inch of the mixed airs is generally as much as can be conveniently managed at a ſingle exploſion; and when any quantity of olefiant gas is preſent, even this quantity will endanger very thick glaſs jars. A very vivid red flame appears at the moment of exploſion, and a great enlargement takes place in an inſtant, after which the bulk is ſuddenly reduced to much leſs than the original quantity. When the carbonic acid is abſorbed, if the gaſſes have been properly proportioned, no gaſeous reſidue is left, except accidental impurities.

The following table will ſhew the relative quantities of pure oxygen required to ſaturate 100 cubic inches of moſt of the known hydrocarbonats, but (as was mentioned in the beginning of this article) though the quantity of carbon contained in each gas may be readily eſtimated, no information is given as to the ſtate of the carbon, that is, whether as ſimple carbon or carbonous oxyd, and therefore the actual quantity of hydrogen is equally unknown.

[f] Henry, Phil. Jour.

TABLE.

One Hundred cubic inches of Inflammable Air (freed from Carbonic Acid).	Oxygen required for fatura-tion.	Carbo-nic Acid produc'd		Pure Carbon.	Oxygen not employ'd for the Carbo-nic Acid.	Hydro-gen which the re-fidue of Oxygen would faturate.	Specific Gravity, Air being 1.000.	Authority.
	cub.inch.	cub.inch.		grains.	cub.inch.	cub.inch.		
from Marfhes - - - - -	150.	72.4	=	9.4	77.6	155.2		Berthollet
—— Silk - - - - - -	150.	88.4	=	11.5	61.6	123.2		Ditto
—— Sugar - - - - - -	100.	80.	=	10.4	20.	40.		Ditto
—— Charcoal - - - - -	138.1	59.5	=	7.74	78.6	157.2		Ditto
—— D° in another experim[t].	75.							Ditto
—— D° - - - - - - -	60.	35.	=	4.55	25.	50.		Henry
—— D° - - - - - - -	66.	40.	=	5.2	26.	52.	.478	Cruikfhank
—— Olive Oil - - - -	132.6	121.	=	15.73	11.6	23.2		Berthollet
—— Lamp Oil - - -	190.	124.	=	16.12	66.	132.		Henry
—— Oak Wood - - -	54.	33.	=	4.3	21.	42.		Ditto
—— Dried Peat - - -	68.	43.	=	5.6	25.	50.		Ditto
—— Cannel Coal - - -	170.	100.	=	13.	70.	140.		Ditto
—— Wax - - - - - -	220.	137.	=	17.81	83.	166.		Ditto
Olefiant Gas - - -	284.	179.	=	23.27	105.	210.	.905	Ditto
—— Camphor - - - -	176.	116.	=	15.08	60.	120.	.660	Cruikfhank
—— Ether - - - - -	170.	108.	=	14.04	62.	124.	.660	Ditto
—— Alcohol - - - -	118.	75.	=	9.75	43.	86.		Ditto
Hydrogen paffed repeatedly over red-hot Charcoal -	49.	21.	=	2.73	28.	56.		Deformes
from Ether - - - - }	equal for equal weights of						.709 }	Dutch Chemifts
—— Alcohol - - - }	the inflammable gaffes						.436 }	
Gafeous Oxyd of Carbon -	40.	92.	=	11 96			.968	Cruikfhank

In the above table it is to be obferved that Berthollet* eftimates the quantity of oxygen required to form a given quantity of carbonic acid gas to be equal in *bulk* to the acid gas, which is nearly accurate; and alfo that two parts in *bulk* of hydrogen with one of oxygen are the proportions in which thefe fubftances unite when they form water. Hence taking the gas from fugar as an example, 100 meafures of it require 100 meafures of oxygen gas, 80 of which are fuppofed to go to form the 80 meafures of carbonic acid actually produced, leaving a refidue of 20 meafures of oxygen, the whole of which is fuppofed to be employed in forming the water that appears after combuftion, and which therefore muft have required twice the bulk, or 40 meafures, of hydrogen gas.

An infpection of the above table will fhew fo great a variety in the proportional refults as to make it evident that no cafual difference in the drying of the gaffes, or accidental circumftances can account for it. For, taking only the two firft columns (thefe being the regifters of actual experiments made by perfons on whofe fkill and accuracy much reliance is to be placed) if there exifted any uniform proportion between the carbonous and the hydrogenous ingredient in all the inflammable gaffes, a fimilar proportion would be found between the refpective quantities of oxygen neceffary to faturation, and the carbonic acid produced; fo that taking the gas from fugar as a general ftandard of comparifon, the gas from marfhes fhould yield 120 cubic inches inftead of 72.4: the gas from filk 120 inftead of 88.4: from charcoal, 110, inftead of 59.5: from olive oil, 106, inftead of 121: from lamp oil, 152, inftead of 124: from wax, 176, inftead of 137, &c. Still however fome tolerable agreement is found between fome of the hydrocarbonats that are obtained from fome of the moft inflammable of the vegetable fubftances or products as from coal, camphor, ether, &c. For taking the gas from coal as a ftandard of comparifon, the gas from wax fhould yield by

* Mem. de L'Acad. for 1785.

oxygen 130, inſtead of 137: from camphor, 104, inſtead of 116: from ether, 100, inſtead of 108: and from alcohol, 69, inſtead of 75, which numbers correſpond tolerably well.

Another circumſtance to be particularly remarked is the very variable quantity of hydrogen which is inferred from the reſidues, a quantity which ſometimes far exceeds and ſometimes as far falls ſhort of 100 cubic inches, the quantity employed, and which obviouſly ſhews ſome great error in the inferences drawn from the experiments. For, taking the gas from coal as an example, ſuppoſing it to anſwer to the general idea of a hydrocarbonat, that is, to conſiſt ſimply of hydrogen gas holding carbon in ſolution, the oxygen required to ſaturate 100 meaſures is ſuppoſed to be divided into two portions, one of them amounting to 100 meaſures, going to form the carbonic acid, and the other amounting to 70 meaſures, entering into the compoſition of the water produced.

But 70 meaſures of oxygen require for this purpoſe 140 meaſures of hydrogen of the ordinary denſity, whereas the whole amount of the inflammable gas is only 100 meaſures, and therefore the hydrogen of which it is compoſed muſt be denſer than common hydrogen at leaſt in the proportion of 14 to 10, even neglecting the ſpace occupied by the 13 grains of charcoal which the gas is alſo proved to contain. But if any of the carbon exiſts in the 100 meaſures of the inflammable gas in the ſtate of the gaſeous oxyd it muſt of courſe occupy more ſpace than when as mere charcoal, and of courſe leſs ſpace can be allowed to the hydrogen, and it muſt be ſtill more condenſed.

This condenſation of hydrogen in the diſtilled products of vegetable inflammables is in itſelf highly probable, and indeed is inferred from the much higher ſpecific gravity of carburetted hydrogen than pure hydrogen; but if this condenſation be allowed in ſome hydrocarbonats, an *oppoſite ſtate* cannot be ſuppoſed in other hydrocarbonats, where the ſpecific gravity is equally great. Yet this inference muſt follow in thoſe caſes where the quantity of hydrogen is inferred as above from the reſidue of oxygen, when it is leſs than the original bulk of the inflammable gas. Thus in the gas from ſugar the eſtimated reſidue of oxygen is only 20 cubic inches, and therefore the hydrogen which it infers is only 40 inches, whereas the quantity of inflammable gas actually uſed was the inches, and therefore were this mode of computation juſt, this carburetted hydrogen ought to be *rarer* than common hydrogen, in the proportion of 4 to 10, a ſuppoſition obviouſly without foundation.

This part of the difficulty may be obviated by the very probable ſuppoſition that a part of the gas conſiſts of the carbonous oxyd, which being mixed with carburetted hydrogen will give the ſame general appearances on combuſtion as ſimple carburetted hydrogen, and being much heavier, will account for part of the great ſpecific gravity of this kind of inflammable air. Where the calculation is merely hypothetical, it may eaſily be ſo arranged as to ſupply by arbitrary quantities of charcoal and carbonous oxyd all the deficiencies of the eſtimated hydrogen. Of this the following will ſerve as an example.

Suppoſe as in the above inſtance 100 cubic inches of the gas from ſugar require 100 inches of oxygen for ſaturation, and produce 80 cubic inches of carbonic acid (which are all the *facts* advanced) then the original 100 cubic inches might be thus diſtributed, without requiring either expanſion or condenſation of the hydrogen.

Inflammable Air from Sugar			Oxygen		Carbonic Acid	
	cub. inch.		cub. inch.		cub. inch.	
Carbon's Oxyd	30	with	12.	produce	27.6	
Hydrogen grains	70	——	35			Water
Charcoal 6.9			53		53.	
	100		100		80.6	

This mixture is of courſe quite arbitrary, and it is obvious that if a condenſation of the hydrogen were ſuppoſed, the proportions might be varied; and it is likewiſe clear that no inflammable gas yielding carbonic acid and water by combuſtion can be properly analyzed till the quantities both of the acid produced, and of the water are ſeparately eſtimated.

As in the above table much confidence may be placed in M. Berthollet's *experiments*, it may be added that on repeating them ſeveral times no material variation was found in any, but in the gas from charcoal, the quality of which varied much according to the heat at which it was produced; and alſo that all the gaſſes were kept for ſome days over water, which is found materially to leſſen the combuſtible matter of thoſe hydrocarbonats that conſume much oxygen, beſides a ſmall addition of azotic air from the water itſelf.

The oxymuriatic acid furniſhes another very uſeful method of decompoſing and analyzing all the hydrocarbonats. Mr. Cruikſhank's accurate and beautiful experiments on this ſubject are highly inſtructive.[h] The pureſt oxymuriatic acid gas is obtained by adding common muriatic acid to the oxymuriat of potaſh, and it ſhould be uſed ſoon after it is obtained, for it in ſome degree loſes its properties by keeping. The oxygen of this gas is ſo looſely combined with the muriatic acid that it quits it when any combuſtible is added, even without the aſſiſtance of the electric ſpark or any other ignited body, and when added to hydrocarbonat both the hydrogen and the carbon are oxydated, and the products are water and carbonic acid, or carbonous oxyd as in common combuſtion, together with the muriatic acid gas now freed from its oxygen and therefore copiouſly abſorbed by water.

Pure hydrogen gas and the oxymuriatic gas were firſt tried: one meaſure of the former with 2 of the latter, mixed in a phial with a glaſs ſtopper and inverted over water, were ſuffered to remain 24 hours. The ſtopper being then withdrawn the whole gaſeous contents were abſorbed, and the water ruſhed into the phial filling it entirely except about $\frac{1}{100}$ of a meaſure which was azotic gas and doubtleſs an accidental impurity. From other experiments Mr. C. found that 2 meaſures of hydrogen required for perfect ſaturation no more than 2.3 meaſures of oxymuriatic gas, and hence as it is eſtabliſhed that to produce water two meaſures of hydrogen are required to 1 meaſure of oxygen, it follows that the 2.3 meaſures of oxymuriatic gas contain 1 meaſure of diſpoſable oxygen, or that portion which makes the difference between ſimple muriatic acid gas and oxymuriatic gas.

The different hydrocarbonats were then tried. Into a bottle filled with and inverted over water one meaſure of carburetted hydrogen from camphor well waſhed, was mixed with 2 of oxymuriatic gas. A ſlight cloud and trifling diminution were perceived, after which the ſtopper was put in and the materials ſuffered to remain together for twenty-four hours. When opened under water all the gas was abſorbed except .43 of a meaſure, and lime water reduced it to .34. This reſidue was ſtill inflammable, but burned with a lambent blue flame like the carbonous oxyd. It was proved to be chiefly carbonous oxyd by the large quantity of carbonic acid which it yielded when fired with oxygen, 2 parts of it with 1 of oxygen giving no leſs than 1.7 of carbonic acid.

In the above experiment the mutual decompoſition of the oxymuriatic acid and the carburetted hydrogen produces no leſs than four new compounds, namely, common muriatic acid, by the loſs of oxygen; water, by the union of the oxygen with the hydrogen; carbonous oxyd by the partial oxygenation of ſome of the carbon; and carbonic acid, by the compleat oxygenation of the remainder.

On increaſing the quantity of oxymuriatic acid to about four times the quantity of the carburetted hydrogen, the whole of the carbon was now found compleatly oxygenated, and every thing was abſorbed by water or lime-water. The products were therefore only muriatic acid, carbonic acid, and water.

Mr. Cruikſhank found a very conſiderable diminution in the quantity of carbonic acid produced, and of courſe of the proportion of the carbonaceous ingredient in the hydrocarbonats from camphor, ether, and alcohol, when they had been long kept over water or agitated with it. A ſimilar difference in the quantity of combuſtible matter was obſerved by Dr. Higgins in the hydrocarbonat from acetite of pot-aſh, which renders it highly probable that theſe hydrocarbonats hold in ſolution ſomewhat of an oily ethereal vapour, or a portion of the true olefiant gas, which water will abſorb. Mr. C. brings the analogy of this ethereal oily part to the vapour of ſulphuric ether. Dr. Prieſtley diſcovered that when ether is agitated with any gas it greatly expands it, and when ſhaken with a large portion of oxygen and ignited, a moſt violent exploſion follows, and the products are water with carbonic acid gas. It appears to be the olefiant part of the hydrocarbonats which cauſes the ſlight diminution that ſome of them *immediately* experience when mixed with the oxymuriatic gas, for with pure olefiant gas the diminution is great and immediate, as will be afterwards mentioned.

Theſe experiments were repeated by Mr. Cruik-

[h] Ph. Jour. vol. v. 4to. p. 202.

thank, with the difference of producing the combuſtion immediately by ignition with the electric ſpark. A remarkable variety in the reſults was, a copious depoſition of charcoal in fine powder after the exploſion of the oxymuriatic and the carburetted hydrogen gaſſes, when the latter was not leſs than half the bulk of the former. In this caſe there was not ſufficient oxymuriatic gas for ſaturation, but when more was uſed, no charcoal was depoſited, but, as might be expected, a greater quantity of carbonic acid was produced. This ſeparation of charcoal only took place with the hydrocarbonats from camphor, ether, or alcohol, and with theſe this property was loſt, by being kept ſome time over water.

Carburetted hydrogen is readily decompoſed by ſulphur, which unites with the hydrogen by ſtronger affinity, forming ſulphuretted hydrogen gas, whilſt the carbon is precipitated as a black ſooty powder.

Dr. Auſtin appears the firſt chemiſt who remarked this fact. His experiment is the following [h]. Some ſulphur and carburetted hydrogen were introduced into a glaſs retort, previouſly filled with, and inverted over mercury. Heat was applied till the ſulphur ſublimed. The melted ſulphur ſoon became red, and as it ſublimed it became quite black, and the retort was covered with a black cruſt. One-third of the air was by this proceſs converted into hepatic air. The remaining two-thirds was carburetted hydrogen not ſenſibly altered. Sulphur and charcoal alſo when heated together in a glaſs retort, yield much hepatic (ſulphuretted hydrogen) air.

The Dutch chemiſts already mentioned alſo found, that when carburetted hydrogen was paſſed over ſulphur kept red-hot in the middle of an earthen tube, the products were ſulphuretted hydrogen gas, and the remaining ſulphur in the tube was blackened by the admixture of charcoal.

Carburetted hydrogen has never yet been applied to any common uſe out of the laboratory, but that which is procured by the diſtillation of coal, is obtained ſo cheaply, and gives ſo much light and heat when burnt in a proper apparatus, that it has been propoſed to be employed for various purpoſes of illumination, to which it ſeems admirably adapted.

Olefiant Gas.

The diſcovery of this very ſingular ſpecies of carburetted hydrogen is due to ſome aſſociated chemiſts of Amſterdam, (Van Deiman, Van Trooſtwyck, Bondt, and Lawrenburgh) in their examination of the different products of the diſtillation of ſulphuric acid and alcohol, in the preparation of *ether*. [k] This gas appears in the common proceſs when the diſtillation is nearly at an end, but where the only object is to obtain it and not the ether, the ſame proportions between the acid and alcohol ſhould be uſed, as may be ſuppoſed to be left in the retort when the common diſtillation of ether is nearly at an end, that is, about four to one; therefore, mix gradually four parts of concentrated ſulphuric acid with one of alcohol, and put them in ſmall bottles uſed for procuring gaſſes. Much heat is given out on mixture, and the colour becomes brown, which gradually darkens to a perfect black when heat is applied. The gas in queſtion begins to be given out at the moment of mixture, and proceeds ſo rapidly that the heat muſt be diſcontinued as ſoon as the materials are become quite black, or they would boil over out of the veſſel.

The gas thus obtained is mixed with a little ſulphureous acid which appears to be more or leſs in quantity according to the greater or leſs heat uſed. It is ſeparated by waſhing the gas with water containing a little ammonia, after which the olefiant gas remains pure. No carbonic acid is ever found mixed with it, though this might be expected from the nature of the materials.

Pure olefiant gas thus prepared is nearly as heavy as common air, being lighter only in the proportion of 905 to 1000. Its ſmell is very fetid after the ſulphureous acid and ethereous vapour are ſeparated by waſhing. It burns with a denſe flame like that of any of the oils or reſins. Water neither abſorbs nor alters it in any degree. None of the common re-agents, gaſſes, acids, or alkalies, produce any notable effect except the oxymuriatic acid, but the phenomena that occur with this acid are very curious.

Equal parts of olefiant gas and oxymuriatic acid gas being mixed together, a diminution of bulk takes place immediately, a viſible vapour fills the veſſel, heat is given out very ſenſible to the hand, and at the ſame time ſeveral drops of a thick pearl-coloured oil appear at the ſurface of the water over which the mixture is made, and immediately ſinks to the bottom.

It is from this ſingular production of denſe oil with the oxymuriatic acid, that this ſpecies of carburetted hydrogen has acquired the name of *olefiant*. When the oxymuriatic and olefiant gaſſes are mixed in about the proportion of four

[h] Phil. Tranſ. vol. 80, p. 66.

[k] Journ. de Phyſ. tom. 40.

to three, the whole is abſorbed excepting accidental impurities, and is converted into oil and water, perhaps with a ſmall portion of carbonic acid.

The oil generated in the proceſs is heavier than water, whitiſh, and ſemi-tranſparent. By keeping, it becomes yellow and limpid. Its ſmell is highly fragrant and penetrating; its taſte, ſomewhat ſweet. It is partially ſoluble in water, imparting its peculiar ſmell. Cauſtic potaſh has no effect on the oil, but only ſeparates the ſmall portion of oxymuriatic acid adhering to it, and renders it more fragrant.

Olefiant gas appears from many experiments to have no other conſtituent parts than carbon and hydrogen, like the purer of the common hydrocarbonats, but contains a much larger portion of theſe ingredients, at leaſt of the carbon.

It is decompoſed by ſulphur like the other hydrocarbonats.

The combuſtion of the olefiant gas offers ſome very curious experiments. When an argand lamp is ſupplied with it inſtead of oil, the flame exceeds every oil and other hydrocarbonat in beauty and brilliance.[l] When mixed with oxygen gas and detonated by the electric ſpark, the exploſion is much more violent than with the common carburetted hydrogen. Mr. Henry found that only .03 of a cubic inch with .17 of oxygen ſhattered a ſtrong glaſs tube; and a Volta's eudiometer $\frac{1}{4}$ of an inch thick, was burſt with leſs than a cubic inch of the mixed gaſſes. It is to be obſerved in all theſe experiments, that when only a ſmall proportion of oxygen is uſed, much leſs than is required for ſaturation, the electric ſpark only kindles the mixture, but without any conſiderable exploſion.

Another ſingular property of the olefiant gas is the copious depoſition of charcoal when it is mixed with a ſmall quantity of oxygen, or with the oxymuriatic acid, and kindled. When the mixture of the oxymuriatic and olefiant gaſſes is made, two or three minutes elapſe before the oil is entirely precipitated, but if this mixture is immediately ſet fire to, no oil is produced, but inſtead, ſo copious a depoſition of charcoal takes place, that the whole veſſel is obſcured, as if it had been covered with lamp-black. No more of the acid gas ſhould be uſed than is neceſſary to produce the combuſtion.

A ſimilar depoſition of carbon takes place when olefiant gas is mixed with juſt enough of oxygen to begin the combuſtion. The Dutch chemiſts[m] found that it required two parts of oxygen to $1\frac{1}{2}$ of the olefiant gas, and when this was ſet fire to by the electric ſpark, the veſſel was entirely blackened with the precipitated carbon.

It ſhould ſeem in the above experiments that the carbon is ſeparated by the abſtraction of a ſmall portion of the hydrogen, and that this latter alone undergoes combuſtion with the oxygen when in ſmall quantity, for on examining the reſidue no carbonic acid was produced. What is very remarkable, the reſidue, notwithſtanding the depoſition of charcoal, and the combuſtion of a portion of the original gas, actually expands to nearly double its former bulk, ſo that in making the experiment in a cloſe bottle, when it is afterwards opened under water, gas ruſhes out from the veſſel inſtead of water flowing in, as might have been expected. The reſidue is now no longer olefiant, but by combuſtion and other properties, it appears to be little elſe than a pure carburetted hydrogen of the common ſpecies.

The great exceſs of carbon condenſed in olefiant gas is alſo ſhewn by the large quantity of oxygen required to ſaturate it, and the quantity of carbonic acid produced. Each of theſe (as expreſſed in the table) is much larger than for every other ſpecies of carburetted hydrogen.

Olefiant gas was procured by the Dutch chemiſts not only from alcohol and ſulphuric acid, but by tranſmitting the vapour of alcohol or of ether through a red-hot earthen tube. The olefiant gas, however, appears not to be quite ſo pure, but to be mixed with common carburetted hydrogen. A very unaccountable circumſtance occurred in theſe experiments. The earthen tube was a tobacco pipe, which yielded olefiant gas very readily, but on ſubſtituting a glaſs tube, the gas was no longer olefiant, but ſimple carburetted hydrogen. This difference did not depend on the poroſity of the earthen tube, for when this latter was encloſed in a glaſs tube the gas was as before, olefiant; and even when the glaſs tube was filled with alumine, or with ſilex, and the vapour ſent through, the ſame effect was produced, but when filled with lime, carbonat of lime, or magneſia, the gas was ſimple carburetted hydrogen.

The whole of this very intereſting part of chemiſtry requires further examination, eſpecially with a view to the formation of the oxyd of carbon, and by ſuch enquiries we may hope to gain ſome knowledge of the great natural proceſſes that are going on in the animal and vegetable kingdoms.

[m] Ann. Chim. tom. 43. p. 127.

CARBONAT OF AMMONIA; or *Sal Volatile. Salt of Hartſhorn.*

This, which is the beſt known of all the ammoniacal ſalts, is always prepared for general uſe by ſublimation, and is found in the ſhops in white compact irregular lumps, ſomewhat reſembling white ſugar in appearance, and of a ſtriated texture.

Carbonat of ammonia is a copious product of the diſtillation of all animal ſubſtances, almoſt without exception, but is actually prepared chiefly from the refuſe part of horn, ivory, bone, &c. Being volatile in a moderate heat it ſoon riſes in diſtillation, and is found diſſolved in the natural watery and oily liquors which alſo diſtil from theſe ſubſtances. It is not from theſe however that this concrete ſalt is immediately prepared, but the impure ammoniacal oily liquor is firſt converted into the MURIAT of *Ammonia* (which ſee) from which the pure carbonat is prepared by the following proceſs. Mix together two parts of dry chalk with one part of dry muriated ammonia in powder, put them into a proper ſubliming veſſel, with the joinings carefully cloſed, and apply a gradual heat. A double decompoſition now takes place, the carbonic acid of the chalk unites with the ammonia, and both riſe together as a denſe white fume, which concretes on the upper and cooler veſſel, and gradually collects into a hard tough cake. The reſidue left in the heated veſſel is the lime of the chalk, united to exceſs with the muriatic acid of the muriated ammonia, and is readily diſſolved out by hot water. The ſublimation ſhould be continued till the lower veſſel is red-hot. The ſame ſimple proceſs (with a ſuitable apparatus) appears to be adopted for the preparation of this ſalt in the large way, as for experiment.

The carbonats of potaſh or ſoda will anſwer as well as chalk in the proceſs, and leſs of them will ſuffice, but there can be no detriment to the product by uſing an exceſs of the carbonat which is to decompoſe the ammoniacal muriat.

The ſolid carbonat of ammonia thus prepared if it is dry, freſh made, or has been kept from the air, is very hard, tough, ſtriated, white, and ſemitranſparent. Its ſmell is extremely pungent, and to moſt perſons agreeable, but when too copiouſly ſnuffed up it excoriates the noſtrils. Its taſte is ſaline and ſtimulating, but with a ſenſe of coldneſs. It gives the uſual teſts of alkalies with vegetable colours. It is very ſoluble in water, and conſiderable cold is produced during the ſolution. At the heat of 55° water diſſolves half its weight, and its own weight at 120°, but with conſtant loſs by volatilization. When a ſolution of this ſalt is kept at a ſcalding heat, a part of the alkali is conſtantly flying off, and the ſolid ſalt thrown upon a hot ſhovel is totally volatile in denſe white fumes. Even at the temperature of the air a conſtant loſs is going on, as may readily be perceived both by the loſs of weight, and by the penetrating ammoniacal ſcent with which a ſmall portion of the ſalt expoſed to the air will fill a large room.

It is extremely difficult to procure this ſalt in any tolerably regular cryſtalline form. Sometimes by ſublimation ſmall needled cryſtals are found cluſtered together, but confuſed. The common method of ſaturating water when hot, and cryſtallizing on cooling, will ſcarcely anſwer on account of the rapid volatilization of the ſalt from a hot ſolution.

Bergman ſucceeded in obtaining tolerably regular cryſtals [a], by taking a concentrated ſolution at a moderate temperature, ſaturating it with carbonic acid, and expoſing it to intenſe cold. The cryſtals, though not quite regular, appeared to be octahedrons with truncated angles.

Carbonat of ammonia contains ſo much carbonic acid that it effervesces moſt vehemently with any of the acids.

This ſalt may be formed by a direct union of its two conſtituents in their gaſeous form, which furniſhes a very beautiful experiment. Fill a jar half full of carbonic acid gas over mercury, then throw up as much ammoniacal gas, alſo over mercury, and as ſoon as the gaſſes come together a very denſe white cloud of precipitated carbonat of ammonia fills the jar, which is immediately followed by a total abſorption of the gaſſes, ſo that if they are pure and properly proportioned, the mercury riſes and fills the jar compleatly, leaving ſcarcely a viſible reſidue. Some heat is given out by this ſudden condenſation.

As the ammonia is by much the lighteſt of the two gaſſes, to produce the condenſation immediately it ſhould be thrown up *after* the carbonic acid gas, and it will of courſe riſe through this latter, mixing with it in its paſſage. If this order is reverſed, the two gaſſes remain ſeparate for a while by the difference of their ſpecific gravities, and the white cloud and condenſation begins from the point of contact of the two, and gradually ſpreads upwards and downwards.

The ſame experiment may be varied without

[a] On the Aerial Acid Eſſays, vol. i.

requiring a mercurial apparatus, by throwing into any glaſs receiver (previouſly filled over water with carbonic acid gas), a ſtream of ammoniacal gas proceeding immediately from a mixture of quick lime and muriated ammonia in the manner deſcribed under the article *ammonia*. A beautiful ſtream of denſe white vapour, which is the precipitated carbonat of ammonia, is ſeen to iſſue from the point where the tube conveying the ammonia touches the carbonic acid gas, and to fall down to the bottom of the receiver. At the ſame time an abſorption takes place, and the water riſes.

A very great variety is found in the relative proportions of carbonic acid, ammonia, and water, in this ſalt, even when the external appearance is nearly the ſame. Beſides, a very conſiderable change takes place by expoſure to air. If a quantity of the hardeſt and moſt pungent freſh carbonat of ammonia of the ſhops (which is ſemitranſparent and of a ſtriated or fibrous texture) be powdered and expoſed to the air on a ſhallow plate in-doors or without, a very remarkable change begins to takes place in a few minutes. A large portion of the ſalt evaporates, filling the room with the pungent ammoniacal odour, and the remainder becomes of an opake white, crumbly and very ſoft, and at laſt perfectly loſes the whole of its ſmell and pungency.

This change is compleated in a few hours, and the loſs of weight is ſo conſiderable, that by ſtanding for a night 100 grains will be reduced to from 48 to 60, more or leſs, according to the quality of the ſalt uſed.

The nature of this change and the compoſition of theſe two kinds of carbonated ammonia on an average calculation will appear by the following experiments.[a] For diſtinction they may be termed the *pungent* and the *mild* carbonat of ammonia.

One hundred grains of the pungent ſalt, ſelected from a quantity recently made and very ſtrong, ſuperſaturated with dilute muriatic acid, with due precaution, were found to loſe on an average about 54 grains of carbonic acid. Another 100 grains diſſolved in water was added to muriated lime, allowing an exceſs of the latter. A conſiderable effervescence took place with the immediate loſs of 12.5 grains of carbonic acid and a precipitation of carbonated lime, which, waſhed, dried, and gently ignited, weighed 89. grains. Of theſe 89 grains, according to the known proportions of this earthy ſalt, 49 grains were lime and 40 grains were carbonic acid, very nearly. Now as there was a copious diſengagement of carbonic acid, all the ammonia with which it was united muſt have paſſed to the muriatic acid of the decompoſed muriated lime, and none of it volatilized. But 49 grains of lime were found to have been ſeparated from the muriat, and the quantity of real muriatic acid requiſite to ſaturate 49 grains of lime is 41.12 grains, according to the known compoſition of this ſalt. Therefore the quantity of ammonia contained in 100 grains of the pungent carbonat is that which is ſufficient to convert 41.12 grains of muriatic acid into muriated ammonia, which, according to Kirwan, is about 25.8 grains. Hence 100 grains of the recent, or *pungent* ammoniacal carbonat may be reckoned to contain 54 grains of carbonic acid, 25.8 grains of pure ammonia, and 20.2 grains of water. It may be added that the quantity of carbonic acid loſt by the effervescence on adding the carbonat of ammonia to the muriated lime is only 12.5, which added to the 40 grains contained in the carbonat makes up only 52.5 inſtead of 54, but the remaining quantity of $1\frac{1}{2}$ of carbonic acid may well be ſuppoſed to be entangled with the precipitate, and to be expelled during the waſhing and ignition.

The *mild* carbonat of ammonia was then in the ſame manner examined. It was perfectly without ſcent, and weighed only 49 per cent. of the pungent carbonat from which it had been procured by expoſure to air for twenty-four hours. One hundred grains loſt alſo by effervescence with muriatic acid on an average 54 grains of carbonic acid, ſo that the quantity of acid in equal weights of the two ſpecies of carbonats appears to be very equal. On adding another 100 grains to muriated lime a much more violent effervescence took place than in the former caſe, with an immediate loſs of 26.5 grains. The carbonat of lime produced was only 58 grs. of which 26 were carbonic acid, and 32 grs. were lime; which, eſtimating as above, would require 26.9 grs. of muriatic acid, and would indicate about 16.2 grs. of pure ammonia in the 100 grs. of the mild carbonat. Hence it may be concluded, that 100 grs. of this ſpecies of carbonat contain on an average about 54 grs. of carbonic acid—16.2 grs. of ammonia—and 29.8 grs. of water.

The change that takes place therefore when the pungent carbonat is expoſed to air, may be probably explained in the following way. All the ammonia exceeding that which is contained in the mild carbonat may be ſuppoſed to be above the true point of ſaturation, ſo that the

[a] Own Experiments.

conſtituent parts may be arranged as follows:—

One hundred parts of the pungent carbonat of ammonia contain

Carbonic acid	54	70.2
Ammonia	16.2	
Ammonia in exceſs		9.6
Water		20.2
		100.0

When this is reduced to 50 parts, and has become mild carbonat, all the exceſs of ammonia appears to be volatilized, and half of the ſaturated carbonat of ammonia, but leſs water in proportion; and when thus reduced, the 50 parts will therefore conſiſt of about

Carbonic acid	27	35.1
Ammonia	8.1	
Water		14.9
		50.0

It ſhould be mentioned that, according to Mr. Davy, the proportion of ammonia in the ſublimed carbonat, much depends on the heat uſed in the proceſs, independent of any ſubſequent volatilization. [b]

Carbonat of ammonia precipitates all the earths from their ſolutions in acids except magneſia, which it only partially decompoſes, attended with particular circumſtances, mentioned under *carbonat of magneſia*.

This ſalt is very ſoluble in all kinds of ſpirits, and as readily riſes with them, as with water, in diſtillation. Advantage is taken of this property in preparing many of the ammoniacal ſpirits and compounds uſed in pharmacy.

The uſe of the carbonat of ammonia is chiefly medicinal. The common dry ſmelling ſalts for the pocket conſiſt of this ſalt a little ſcented.

CARBONAT OF POTASH. *Kohlenſaure gewächſalkali*, Germ. *Carbonate de Potaſſe*, Fr.

POTASH. PEARLASH. *Gemeine Pottaſche. Calcinirte Pottaſche*, Germ. *Salin. Potaſſe*, Fr.

SALT OF TARTAR. *Weinſteinlaugenſalz*, Germ. *Sel de Tartre*, Fr.

In this article we ſhall firſt treat of the method of procuring the vegetable fixed alkali, and the different forms under which it appears in commerce and domeſtic uſe, and ſhall then notice the preparation and characters of that neutral ſalt properly called, according to the modern chemical nomenclature, *Carbonat of Potaſh*.

The vegetable fixed alkali was ſo named by the chemiſts of the laſt and former ages, becauſe it was procured in large quantities from vegetable ſubſtances, and was in no caſe ſuppoſed to be of mineral origin. From certain late analyſes, however, by Klaproth and other able chemiſts, it has been diſcovered to enter, as an eſſential ingredient, into the compoſition of leucite, lepidolite, and a few other minerals, which are by none ſuſpected of deriving their origin from organized bodies. But though the exiſtence of potaſh in a mineral ſtate has been thus demonſtrated, yet it is ſo ſmall in quantity, and ſo difficultly procurable, that all the vaſt ſupplies of this ſubſtance which civilized life requires, have as yet been entirely obtained from the combuſtion of vegetables.

If the woody or annual ſtems of vegetables, that have grown in ſoils unimpregnated with common ſalt, after being ſufficiently dried are ſet fire to, the watery, the reſinous, the oily, the acid and carbonaceous portions are volatilized and diſſipated in a ſtate of more or leſs compleat decompoſition, and there remains behind a reddiſh or whitiſh powder, called *aſh* or *aſhes*; conſiſting chiefly of the earthy and metallic ingredients of the vegetables, together with a variable proportion of ſub-carbonat of potaſh. By lixiviation with hot or cold water the alkaline part is diſſolved out, and this ſolution when boiled down to dryneſs leaves behind a dark brown ſaline maſs, conſiſting of the carbonated potaſh, coloured by a ſmall portion of vegetable inflammable matter; and in this ſtate it is known in the Engliſh market by the name of *potaſh*. Calcination at a moderate red heat compleatly burns off the colouring particles, and the ſalt becomes of a ſpungy texture, and beautiful bluiſh white tinge, and is then called *pearlaſh*. Such is in general the proceſs by which the vegetable fixed alkali is ſeparated from the ſubſtances with which it is combined by nature, and prepared for uſe. We ſhall now proceed to deſcribe more at large the different methods of extracting this ſalt, together with the precautions that are neceſſary to ſecure the greateſt ſucceſs.

The ſimpleſt and rudeſt preparation of potaſh is called *aſh-balls* in England, and *weed-aſh* in Ireland. It cannot be ſaid properly ſpeaking to be an article of commerce, although a conſiderable quantity is annually made by the peaſantry of both countries, and diſpoſed of among the neighbouring farmers and bleachers. The vegetable from which this impure alkali is produced is the common fern or brakes (Pteris aquilina *Lin.*) Many rough and heathy diſtricts are entirely covered with this plant, which

[b] Reſearches, p. 75.

when it has attained its full growth, (which happens about the middle of July) is cut down, and after being half-dried in the open air, is gathered into ſmall heaps and kindled. The combuſtion proceeds ſlowly, being accompanied by a ſmothering ſmoak and little or no flame, till the whole is reduced to a reddiſh grey aſh: this being carefully collected is ſprinkled with a little water, and then moulded by hand into balls from three to four inches in diameter, which when they have acquired a certain hardneſs and ſolidity by drying in the ſun, are ready for ſale. In Ireland, thiſtles, docks and weeds of all kinds are mixed with the fern, and the aſhes are diſpoſed of in their looſe pulverulent ſtate without any further preparation. According to Dr. Home fern-aſhes contain about $\frac{1}{5}$ of their weight of ſalt, conſiſting principally of ſub-carbonat and ſulphat of potaſh. 1000 parts of the plant cut in Auguſt, and thoroughly dried, afford 36.46 of aſhes, from which are obtained by lixiviation 4.25 of ſalt. The common Iriſh weed aſhes have been analyzed by Mr. Kirwan; and when deprived of their water by a red heat appear to contain 1 part of ſalt for $3\frac{1}{2}$ parts of aſh; of this the free alkaline portion however, as deduced from the quantity of alum decompoſed by the lixivium, amounted only to $\frac{1}{22}$ of the whole.[c]

The *potaſh* of commerce, or *black potaſh*, as it is alſo called, is univerſally procured from the combuſtion of wood; and therefore its preparation can only be undertaken with ſucceſs in thoſe uncleared countries in which are vaſt natural foreſts, and where from the badneſs of roads, and imperfection of water communication, the value of timber is no more than that of the labour employed in felling it. The only diſtricts in Europe in which any conſiderable quantity of potaſh is made, are the mountainous foreſts of Germany, and the extenſive woodland tracts of Poland and Ruſſia. The Britiſh market however is principally ſupplied from the United States of North America; a country in which from its rapid increaſe in population there is a conſtant demand for cleared land for the purpoſe of cultivation, and therefore timber is looked upon rather as an incumbrance, than as contributing either to the beauty or value of the ground on which it ſtands.

The moſt waſteful method of manufacturing potaſh is that practiſed by the Americans, partly on account of the ignorance of the people by whom it is prepared, but principally becauſe this employment is carried on rather as ſubſidiary to clearing the ground for agriculture than on its own account. The wood as ſoon as it is ſufficiently dry to burn is collected into large piles and reduced to aſhes: theſe aſhes are then put into a wooden ciſtern, with a plug at the bottom of one of the ſides, and a quantity of water ſufficient to make a ſtrong lixivium is added: after ſtanding for an hour or two the plug is withdrawn, and the water holding the potaſh in ſolution runs clear out, leaving the earthy part ſtill impregnated with alkali in the ciſtern. This ſolution is then evaporated to dryneſs in iron pans, and haſtily fuſed into compact reddiſh brown maſſes of ſemi-cauſtic potaſh, in which ſtate it is fit for the market.

In Germany, where potaſh is prepared on its own account, and where a greater degree of intelligence and economy is practiſed, the general method of proceeding is the ſame as that juſt mentioned, but with ſuch variations as, though ſeemingly of little conſequence, materially augment the produce of alkali. Care is taken to ſelect ſuch kinds of wood as are the richeſt in potaſh; the combuſtion is ſlower, and of courſe the temperature lower, in conſequence of which but little is loſt by volatilization; the lixiviations of the aſhes are alſo judiciouſly repeated till the whole of the alkali is extracted.

The common Ruſſian potaſh is the impureſt of all, containing nearly one half its weight of earth, and is thus prepared. A large pit is dug, into which are thrown burning brands and the ſmaller extremities of the branches, and when the whole is well kindled the pit is filled up with logs and other large pieces, which at length, though very ſlowly, are reduced to aſhes. The coarſer part of the aſhes is then ſeparated by ſifting from the finer; all the alkali that it contains is procured by lixiviation; and this liquor is mixed with the remainder of the aſhes and worked together into a kind of paſte. A pile is then built of alternate ſtrata of wood and this paſte, and being ſet fire to the whole is again reduced to aſhes. This proceſs is repeated ſeveral times till the aſhes begin to clot and become hard: the moſt compact pieces being then ſelected, are packed up for ſale without any further preparation; the reſt are lixiviated and boiled down to dryneſs in the uſual manner.

In ſome parts of Germany potaſh is made from the empyreumatic acid produced from wood while burning into charcoal. By means of wide tubes of plate iron or copper, the acid

[c] Iriſh Tranſactions.

and oil which would otherwiſe be diſſipated in the air, are collected; the watery acid part being then ſeparated from the other is evaporated to dryneſs, and the reſiduum by calcination affords an aſh extremely rich in alkali.

Potaſh is converted into a much purer alkaline ſalt called *pearl-aſh*, by calcination: for this purpoſe, the potaſh broken into moderately ſmall pieces, is ſpread on the floor of a reverberatory furnace, and being then kept red-hot, but not melted, for an hour or two, ſtirring it occaſionally with an iron rake, all the carbonaceous and colouring particles are burnt out, and there remains behind a dry porous and conſiderably cauſtic ſalt, extremely deliqueſcent, and from its bluiſh white colour called pearlaſh.

It has been thought of conſequence in an economical point of view to diſcover the proportion of potaſh afforded by different vegetables, and many analyſes have been made for this purpoſe. They are however for the moſt part unſatisfactory, as they indicate only the quantity of ſoluble ſaline ingredients without diſtinguiſhing the carbonated potaſh from the ſulphat and muriat of potaſh with which it is always mixed. The moſt remarkable and intereſting reſults will be found in the following table, part of which were aſcertained by a Committee of the Academy of Sciences at Paris, and the reſt by the chemiſts whoſe names are ſubjoined. 100 parts of each different ſpecies, being previouſly thoroughly dried, were burned by an open fire to aſhes, which, after being weighed, were accurately lixiviated till all their ſaline contents were extracted.

100 parts	Aſhes	Salt	Salt from 100 parts of Aſhes	
Fumitory	21.9	7.9	36.	Wiegleb
Wormwood	9.74	7.3	74.8	Ditto
Common Nettle	10.67	2.5	23.4	Pertuis
Sow Thiſtle (Sonchus arvens.)	10.5	1.96	18.6	Ditto
Fern	5.	0.62	12.5	Ditto
Ditto	3.64	0.42	11.6	Home
Stalks of Maize	8.86	1.75	19.7	
Ditto Sunflower	5.72	2.	34.9	
Buckwheat			33.3	Vauquelin
Vine branches	3.4	0.55	16.2	
Heath			11.5	Wildenheim
Foxglove (digitalis purpurea)			33.	Leipſic econ. Soc.
Celandine (Chelidonium maj.)			25.	Ditto
Nightſhade (atropa bellad.)			27.	Ditto
Boxwood	2.9	0.22	7.8	
Sallow	2.8	0.28	10.2	
Elm	2.3	0.39	16.6	
Oak	1.3	0.15	11.1	
Beech	0.58	0.12	21.9	
Aſpen	1.22	0.07	6.1	
Fir	0.34	0.04	13.2	

Upon a curſory inſpection of this table, it appears that the ſucculent herbaceous plants afford a prodigiouſly greater proportion both of aſhes and ſalt than the ſhrubby and ligneous ones: it is however to be obſerved, that they were all reduced to a ſtate of perfect dryneſs before being weighed, a circumſtance which will in a conſiderable degree account for the apparently greater quantity of ſalt contained in the ſucculent vegetables; for while the different kinds of wood will not loſe more than $\frac{1}{5}$ or even $\frac{1}{6}$ of their weight in drying, fumitory will probably loſe $\frac{9}{10}$ or even more. It is not likely therefore that it can be ever worth while, as ſome ſpeculators have propoſed, to be at the expence of cultivating fumitory and wormwood, for the ſake of the potaſh contained in their aſhes.

It has been a ſubject of enquiry among chemiſts whether the potaſh that is obtained by the combuſtion of vegetables is formed by this proceſs, or only diſengaged by the decompoſition of

thoſe acids and other vegetable principles with which it was before united. The former of theſe opinions was adopted by Macquer and many of the eminent chemiſts that were contemporary with him, but of late the latter opinion has been rather gaining ground. The principal arguments by which Macquer ſupports his theory are the following[d]. 1ſt. When vegetables, capable of furniſhing much alkali by combuſtion, are decompoſed in any other way, no other ſaline products are obtained but liquid and concrete acids. 2d. When vegetables are deprived of part of their acid by diſtillation the produce of alkali is proportionately diminiſhed. 3d. The concrete acids, as tartar, are changed into alkali merely by combuſtion. 4th. Plants that yield little or no acid in diſtillation are found after combuſtion to afford little alkali. 5th. Plants, which when burnt without any previous alteration, yield much alkali, if burnt after undergoing compleat putrefaction, afford no alkali.

In oppoſition however to theſe arguments it may be obſerved, 1ſt. That the native concrete oxalic, and tartareous acids have been proved by modern chemiſts to be acidulæ, or in other words to contain potaſh, though not to full ſaturation of the acid; and therefore when theſe are burnt no converſion of acid into alkali takes place, but the acid being volatilized and decompoſed, the alkali which was before maſked by an exceſs of acid now exhibits itſelf with its uſual characters. 2d. Nitre compleatly formed has been diſcovered in borrage and ſome other vegetables, therefore the exiſtence of potaſh, the alkaline baſe of this ſalt, is alſo neceſſarily demonſtrated. 3d. Vauquelin has ſhown that the ſap of trees contains acetite of potaſh. 4th. The reaſon why vegetables after putrefaction yield no alkali is that their texture being broken up by this proceſs, the water which drains through the maſs diſſolves and carries off all the alkali which they at firſt contained. This is manifeſt from the experiments of Mr. Birch,[e] who, by evaporating and calcining 24 wine-pipes, or 3024 gallons, of dunghill water, procured 1048 lbs. of good marketable potaſh. We may therefore conclude that the potaſh obtained by lixiviation of vegetable aſhes pre-exiſted in the plants themſelves: whether this alkali is formed during the proceſs of vegetation, or is only imbibed from the earth by the roots, is not as yet determined.

The varieties of pot and pearlaſh which are found in the market would no doubt on analyſis afford very different reſults, eſpecially with regard to the proportions of earthy matter, of water, and of carbonic acid; it is not therefore perhaps much to be regretted that we poſſeſs no very accurate analyſis of any of them. The only one on which any reliance can be placed is of Dantzic pearlaſh by Mr. Kirwan,[f] in which are contained about

60.3	potaſh
22.4	carbonic acid
7.2	water
8.7	ſulphated potaſh
0.7	muriated ditto
0.7	earth
100.0	

But if the analyſis of any particular ſample is of little conſequence generally ſpeaking, yet it is of conſiderable importance both to the manufacturer and chemiſt, to be in poſſeſſion of a compendious and accurate mode of aſcertaining the contents of the various kinds of pot and pearlaſh, in order to make advantageous purchaſes of articles, in the intrinſic worth of which there is ſo much difference.

Mr. Kirwan's method of calculating the proportion of real alkali, in a given lixivium, from the quantity of precipitate which it throws down from a ſolution of alum, is by no means to be depended on; for in the firſt place the ſilex and alumine which the lixivium holds in ſolution, are precipitated together with the earth of alum; and in the ſecond place ſo much depends on the degree of waſhing and calcination which the precipitate is made to undergo, that from equal quantities of alum it is ſcarcely poſſible to obtain equal weights of earth. Upon the whole therefore perhaps the beſt mode of proceeding is as follows.

1ſt. Prepare a diluted ſulphuric acid by mixing the concentrated acid, called oil of vitriol, with three times its bulk of diſtilled water. Then teſt it by taking 100 grains of the diluted acid, and adding muriat of barytes as long as any precipitate falls down. The ſulphat of barytes thus prepared when waſhed with cold water, and dried at a low red heat, contains 33.3 per cent. of ſulphuric acid, hence the real acid in any quantity of the diluted acid is readily aſcertained.

2d. Pulverize 500 grains of the alkali under examination, and digeſt it in warm water, adding freſh portions of this fluid as long as any

[d] Macquer's Chem. Dic. art. Alkali.
[e] Phil. tranſ. for 1780, p. 345.
[f] Examin. of the alkaline ſubſtances uſed in bleaching.

thing is diſſolved. Then put all the ſolutions together, and drop in the teſted ſulphuric acid from a vial containing a known weight of the ſame, till the ſlighteſt poſſible exceſs of acid is indicated by a paper tinged with litmus. After this, heat the mixture to expel all the carbonic acid, and if the liquor changes turmeric paper add a few drops more of ſulphuric acid till it ceaſes to ſhow an exceſs of alkali. Now weigh the vial of ſulphuric acid, and thus aſcertain how much has been expended in ſaturating the alkali, and for every 100 parts of real acid (as previouſly determined by muriat of barytes) thus employed, ſet down 121.2 of pure potaſh. The alkali being the part which gives value to the whole, this is all the examination which in ordinary caſes is required, but if the analyſis is to be carried further—

3d. Take 500 grains more of the alkali, diſſolve it in boiling water and pour the ſolution into a flaſk; then place the flaſk and a vial containing from two to three ounces of pure nitric acid into one ſcale of an accurate balance and equipoiſe them. Afterwards add the acid by degrees to the alkali as long as any effervеſcence takes place, and the loſs of weight indicates the amount of carbonic acid. The ſolution will now probably cryſtallize, a ſufficient quantity of water is therefore to be added in order to diſſolve the cryſtals, and nitrat of barytes is to be dropped in ſo long as any precipitate takes place. 100 parts of the dried ſulphat of barytes thus procured indicate 73.6 of ſulphated potaſh. This being removed, add to the clear liquor nitrat of ſilver till it ceaſes to be decompoſed. 100 parts of muriated ſilver ſhow 41.34 of muriated potaſh. Thus the ſaline contents are all of them aſcertained, viz. potaſh, carbonic acid, ſulphat and muriat of potaſh. The earthy part is ſhown in the inſoluble reſidue, No. 2, and in the precipitate which falls down on boiling the alkaline liquor after its ſaturation with ſulphuric acid. If any ſulphur is contained in the alkali, as is the caſe with the black potaſh, this will fall down together with the earth upon ſaturation with ſulphuric acid, and is ſeparated from the earth by a red heat.

Having now treated of the impure ſubcarbonats of potaſh we ſhall conclude this article with an account of the purer ſubcarbonats and the perfect carbonat of potaſh.

The moſt important of the purer ſubcarbonats is *ſalt of tartar*, which is prepared in the wine countries in conſiderable quantity, and is the kind generally uſed in medicine. The lees of wine and the tartar that is depoſited on the ſides of the caſks are put into ſmall bags about a foot long, and ſubjected to a ſtrong preſſure in order to ſqueeze out all the wine which is diſpoſed of to the brandy diſtillers; the contents of the bags being carefully taken out, without breaking, form maſſes like loaves, which are dried in the ſun, and then piled up in a furnace with alternate ſtrata of charcoal. The fire being kindled, and the draft properly regulated, the acid and inflammable matter of the tartar is burned off without fuſing the alkaline part; when the proceſs therefore is finiſhed, the loaves remain of nearly the ſame ſize as before, but very porous and perfectly white. Being then broken into pieces they are diſſolved in hot water, and the clear lixivium being evaporated to dryneſs and then ſlightly calcined is fit for ſale. $2\frac{1}{2}$ parts of tartar yield one of ſalt of tartar.

A more expeditious but leſs economical way of procuring ſalt of tartar is to mix equal parts of crude tartar and nitre, and project the mixture into a red hot crucible. A rapid deflagration takes place, the nitric acid, and the combuſtible parts of the tartar mutually decompoſe each other, and there remains behind the alkaline baſe of each united with ſome carbonic acid. This preparation is called *white flux*, *nitre fixed by tartar*, *extemporaneous potaſh*.

The perfectly ſaturated carbonat of potaſh has not been known to chemiſts longer than the time of Bergman. It may be prepared in two ways: the firſt, which was diſcovered by Berthollet, is as follows. Take equal parts of ſalt of tartar and carbonat of ammonia, diſſolve the whole in warm water, then pour the ſolution into a retort, and proceed to ſlow diſtillation; the potaſh having a ſtronger affinity for carbonic acid than ammonia has, deprives this latter of its acid, and in conſequence ammoniacal vapour is given out in great quantity: when this ceaſes, the contents of the retort are to be poured into a convenient veſſel, where, by refrigeration, a copious depoſition of cryſtallized carbonat of potaſh will take place.

The other method, and that which is generally practiſed, is to put a ſolution of ſalt of tartar into an apparatus for impregnating water with carbonic acid, and then to throw in this acid till the alkali is quite ſaturated, and refuſes to take up any more; on opening the barrel, it will be found lined with large cryſtals of carbonated potaſh.

The form of its cryſtals is that of a tetrahedral rhomboid with dihedral ſummits. It requires for its ſolution about 4 parts by weight of cold water, but diſſolves in $\frac{1}{2}$ of its weight

of boiling water: a conſiderable abſorption of caloric takes place during its ſolution. It is hardly at all ſoluble in cold alcohol, and requires above 200 parts of this fluid when boiling for its compleat ſolution.

It has been analyſed both by Bergman and Pelletier: each of theſe chemiſts agrees in the proportion of alkali, but they differ materially in their eſtimation of the water, and carbonic acid.

Bergman	Pelletier
48	48 potaſh
20	43 carbonic acid
32	9 water
100	100

The taſte of this ſalt is cool and freſh with hardly any of the alkaline flavour; on which account, and becauſe it is fully ſaturated with carbonic acid, it is greatly preferable to common ſalt of tartar in the compoſition of effervescing drafts, and for other medical purpoſes. It is neither efflorescent nor deliqueſcent in the air. It is decompoſable with abſtraction of its acid by barytes, and lime, and ſtrontian, and with abſtraction of its alkali by all the mineral, and almoſt all the vegetable acids.

The uſes of potaſh are innumerable. It is conſumed in the greateſt quantities by ſoap-boilers, bleachers, and glaſs-makers. In the laboratory it is in conſtant and indiſpenſable ſervice.

CARBONAT OF SODA. *Carbonate de Soude*, Fr. *Kohlenſaure mineraliſche gewachſalkali*, Germ.

KELP. *Soude de Varech*, Fr. BARILLA. NATRON.

This ſalt is found to exiſt both in the mineral and vegetable kingdoms of nature. When mineral, it is met with either diſſolved in the water of certain hot ſprings, as thoſe of Carlſbad in Bohemia, and Rykum in Iceland, or of certain lakes, as the natron lakes of Egypt and Hungary; or it occurs in the ſtate of a ſolid ſalt as the foſſil natron of Tripoli, called Trona.—In the vegetable kingdom carbonat of ſoda has been proved to exiſt ready formed in the ſalſola ſoda, and in all probability is contained in all thoſe ſucculent ſaline plants that grow in places impregnated with muriat of ſoda. In order to ſupply the vaſt demands for carbonated ſoda it is procured from both the ſources above-mentioned by proceſſes which we ſhall now relate, beginning with the mineral ſoda.

There are two varieties of mineral ſoda, the ſtriated and the compact. The ſtriated has hitherto been procured only from Africa. It is found in the province of Sukena, between Tripoli and Fezzan, forming a very thin ſtratum juſt below the ſurface of the ſoil: it is of a ſtriated cryſtalline texture reſembling ſtriated gypſum, and from ſome ſpecimens deſcribed by Dr. D. Monro,[a] the ſtratum (which does not exceed an inch in thickneſs) is in contact both above and below with common ſalt. From the account of Mr. Bagge, however, it appears that the natron diſtrict is at a conſiderable diſtance from the ſalt mines, and the analyſis of this ſubſtance by Klaproth exhibits no trace of muriatic acid in its compoſition. It is collected to the amount of ſome hundred tons annually, but ſcarcely ever finds its way to the European markets. It is characteriſtic of the ſtriated ſoda that its cryſtals inſtead of effloreſcing as this ſalt uſually does, remain permanent in the air, a circumſtance that is to be attributed to the comparatively ſmall quantity of water of cryſtallization that it contains, and to the compleat ſaturation of its alkaline baſe by carbonic acid. Common carbonated ſoda conſiſts of

22	ſoda
16	carbonic acid
62	water
100	

whereas the trona, according to an accurate analyſis of it by Klaproth,[b] conſiſts of

37	ſoda
38	carbonic acid
22.5	water
2.5	ſulphated ſoda
100.0	

The compact mineral ſoda or natron, although contained in the waters of ſeveral ſprings and lakes, is procured in quantity only from Egypt and Hungary. The Egyptian natron lakes, ſix in number, are ſituated in a barren valley, called Bahr-bela-ma, about thirty miles weſtward of the Delta. During three months in the year they are ſupplied with water from copious ſprings that burſt out from the weſtern ſide of the valley, but as they receive no water during the reſt of the year ſome of the ſmaller and ſhalloweſt ones are generally dried up during the ſummer. The ſoil conſiſts of calcareous rock mixed with gypſum, and for the moſt part

[a] Phil. Tranſ. lxi. p. 567

[b] Analyt. Eſſ. ii. p. 63.

covered over with ſand. The ſalts contained in theſe lakes are muriat and carbonat of ſoda, and it is remarkable that the proportions of theſe two not only vary in the different lakes but in different parts of the ſame lake, ſo much ſo that the cryſtalline depoſits at that extremity of the lake which is the ſhalloweſt, and in which ruſhes grow, are principally carbonat of ſoda, while thoſe formed at the oppoſite extremity are almoſt entirely common ſalt. The lakes are ſurrounded with a band, ſome yards in breadth, of ſaline efflorescences, but the principal accumulations of ſalt are in the water at a little diſtance from the bank. The natron appears to be formed by the ſlow mutual decompoſition of the lime-ſtone and common ſalt aſſiſted by the ruſhes, up the ſides of which the natron riſes by the force of efflorescence: when the ruſhes thus incruſted are broken by the wind, the ſoda on their ſurface aſſumes its proper quantity of water, and forms a confuſedly cryſtallized ſtratum of the thickneſs of from one to twelve inches, according as the weather and other circumſtances are more or leſs favourable to its production. In moſt of the lakes the depoſition of natron takes place only at certain periods, in the intervals of which cryſtals of common ſalt are produced ſo that the ſaline maſſes which are dug out, eſpecially in thoſe parts that have been long undiſturbed, preſent alternate ſtrata of muriat and carbonat of ſoda. The efflorescences on the ſhore of the lakes, and the detached cryſtals that form in abundance at the water's edge are mixed with a much ſmaller quantity of common ſalt than the more compact maſſes, theſe latter however being rather more convenient to carry, and being procured with leaſt trouble are conſtantly preferred, and as no ſubſequent purification is had recourſe to, the natron of Egypt is by no means ſo valuable as it might eaſily be made. It is chiefly exported to Greece and other parts of Turkey, to Venice, to France, and Britain.[c]

The natron lakes in Hungary, like moſt of the natural advantages of that rich country, are in a ſtate of exceſſive neglect: the only ones that are put to any uſe are four that lie between Dobritzin and Grofwaradin. Theſe in the winter ſeaſon, when full of water, are from one to two miles in circumference, but by the middle of April or the beginning of May they are generally dried up, except ſome pits that have been ſunk by art below the general level. In a few days after the water has diſappeared, the whole ſurface of the cavity becomes white with ſaline efflorescences of natron mixed with a little ſulphat of ſoda: theſe being removed, a freſh incruſtation is formed in three or four days, and continues to be renewed with equal rapidity during the whole dry ſeaſon of the year. A very heavy ſhower is ſufficient to fill the lakes, but in a day or two they are dry again, ſo that no conſiderable interruption is experienced till the latter end of October; by this time the water in the pits is fully ſaturated with natron, a conſiderable proportion of which cryſtallizes during the firſt froſts of autumn, and thus finiſhes the harveſt of the year, for after this the rains ſet in, and the lakes continue full of water till the enſuing ſpring. The ſoil is a ſtiff blue clay covered by a white calcareous ſand, and is probably impregnated with ſalt as the ſalſola and other ſucculent ſaline vegetables flouriſh here in great abundance.[d] The Hungarian as well as the Egyptian natron ſeems to be brought into commerce without undergoing any preparation, as it appears in pulverulent maſſes of a dirty grey colour. The Hungarian natron has been analyſed by Lampadius, and the Egyptian by Klaproth,[e] with the following reſults.

Egyptian natron		Hungarian natron	
32.6	—	14.2	Carbonat of Soda
20.8	—	9.2	Sulphat of Soda
15.	—	22.4	Muriat of Soda
31.6	—	45.	Water
		9.2	Earthy reſidue
100.0	—	100.0	

By far the greater part however of the ſoda that is employed is of vegetable origin, and like potaſh, is procured from the combuſtion of plants. While the vegetables that grow in common ſoil yield potaſh, thoſe which flouriſh in ſalt water, or on the ſea ſhore, or wherever the ground is ſtrongly impregnated with ſalt yield ſoda. Of vegetable ſoda there are two varieties, namely, barilla and kelp; the former being made from the plants of the genera ſalſola, ſalicornia, &c. that grow on the ſea ſhore, the latter being the produce of fuci and other marine plants.

The beſt barilla is made from the ſalſola ſoda, which is an object of extenſive and ſedulous cultivation to the Spaniards, on the ſhore of the Mediterranean, eſpecially in the vicinity of Alicant. It is ſown in light low ſoils that are embanked on the ſide next the ſea, and furniſhed with flood-gates, by which the ſalt water may be let in occaſionally. In autumn when the

[c] Memoirs ſur l'Egypte. [d] Jour. des Mines, No. 2. p. 117. [e] Analyt. Eſſ. ii. p. 60.

ſeeds are ripe, the crop is cut down and dried; the ſeeds are rubbed out, and the reſt of the plant is burnt in very ſimple furnaces, the temperature of which is juſt high enough to cauſe the aſhes to enter into a ſtate of ſemifuſion, and concrete into compact cellular maſſes. The moſt eſteemed variety of this ſalt is called *ſweet barilla*; it is of a greyiſh blue colour, and is covered over with a ſaline efflorescence when expoſed for a time to the air: it is exceedingly hard, and when applied to the tongue diſcovers a ſharp pungent alkaline flavour.

We poſſeſs an intereſting analyſis of the ſalſola ſoda by Vauquelin:[f] a remarkable quantity of azot enters into the compoſition of this vegetable, thus giving it a ſtriking analogy to animal matter. 500 parts of the recent plant when carefully burnt afford oil and ammonia, and pruſſic acid, and leave behind 100 parts of aſhes. 500 grains of the aſhes when carefully lixiviated afford 113 grs. of muriated ſoda, and 159 grs. of cryſtallized (68 grs. of dry) carbonat of ſoda, the inſoluble reſidue conſiſts of 204 grs. carbonated magneſia, and 100 grs. of ſand and oxyd of iron; to which are to be added 23 grs. of water not as a neceſſary but an accidental part, and therefore ſubject to conſiderable variation.

The Alicant barilla being compoſed of the ſame ſalſola ſoda, contaminated in ſome degree with weeds and other impurities that are unavoidable where a large quantity of materials is operated on, ought to bear a conſiderable reſemblance in its analyſis to that of ſalſola ſoda juſt mentioned. Mr. Kirwan[g] has examined the component parts of ſweet barilla, but unfortunately we are not able to trace the ſmalleſt ſimilarity between the reſults of his analyſis and that of Vauquelin: according to him a pound troy of barilla contains

1219	842	Dry cauſtic ſoda
	250	ditto impure
	127	ditto mixed with muriated ſoda
	125	Sulphat of ſoda
	70	Muriat of ſoda
	960	Carbonic acid
	542.86	Lime
	127	Magneſia
	131.23	Alumine
	249.58	Silex
	20	Unexamined earth
	861.32	Charcoal
	4306.49	
	1453.51	Water
	5760.00	

A minute examination however into the experiments upon which the above proportions are founded will diſcover ſome inconſiſtencies which forbid us to place an implicit reliance on them. Theſe we ſhall mention, not with a view to depreciate the well earned reputation of Mr. K. but to ſhow the neceſſity of a further examination into a ſubject ſo intimately connected with ſome of our moſt important manufactures. It appears from Mr. K's experiments that of the whole 5760 grs. of barilla, 2857 were ſoluble in water, the inſoluble reſidue when reduced to the ſame apparent dryneſs as the original barilla, amounting to 2903 grs. or ſomewhat more than one half. Now 480 grs. (or one ounce) of the entire barilla when treated with muriatic acid loſt 80 grs. of carbonic acid, therefore the whole quantity of carbonic acid in a pound of barilla $= 80 \times 12 = 960$ grs. But 480 grs. of the inſoluble reſidue yielded by the ſame treatment 125.5 grs. of carbonic acid, and as the whole quantity of this amounted to ſomething more than 6 ounces, the total amount of carbonic acid in the reſidue is $= 125.5 \times 6 = 753$ grs. Hence 960 grs. — 753 = 207 grs. indicate the quantity of carbonic acid contained in the ſoluble part of the barilla. But 207 grs. of carbonic acid indicate only 491.6 of dry, or 1293 grs. of cryſtallized, carbonat of ſoda, and it is not probable that the ſoda contained in the barilla was very cauſtic, ſince Mr. K. obtained cryſtals from the lixivium without, as appears, taking any meaſures for ſaturating the alkali further than performing the evaporations and coolings, to the number of 18 in the open air. Another objection ariſes from the amount of carbonic acid in the inſoluble reſidue. The only ingredients in the reſidue capable of uniting with carbonic acid are the lime and magneſia,

but 543 grs. lime require	444.2 carbonic acid
and 127 grs. magneſia	95.9
	540.1

The whole amount however of carbonic acid contained in the reſidue is $= 753$ grs. therefore $(753 - 540.1 =)$ 212.9 grs. of carbonic acid remain, without any baſe with which they can combine.

It is alſo obvious that the amount of charcoal is exceſſively exaggerated. The inſoluble reſidue containing the charcoal, was, after a long lixiviation with hot water, dried in a heat below redneſs, and was then ſuppoſed to have loſt all its water, it was then calcined at a white heat,

[f] An. de Chim. xviii. p. 76. [g] Examination of Alkalies uſed in bleaching.

and the whole loſs of weight, deducting that of the carbonic acid thus expelled, was ſuppoſed to be the weight of the charcoal: but charcoal that had been ſoaked in hot water can by no means be dried at a temperature below a red heat, and therefore a large deduction muſt be made from the charcoal, on account of the water contained in it.

On referring to the reſults of the analyſis we find 250 grs. ſet down as dry cauſtic ſoda, but ſomewhat impure: this is entirely founded on a groſs blunder. Among the cryſtalline ſalt depoſited by the lixivium was a portion of 346 grs.: this conſiſted of "a mixture of vegetable "and mineral alkali, with a proportion of ex-"tractive matter and ſome digeſtive ſalt." The "mere alkali" contained in this is eſtimated by Mr. K. at 253 grs.: but this is impoſſible, for 250 grs. of mere ſoda would produce 1136 grs. of carbonated ſoda, whereas the ſalt in queſtion with all its impurities, amounted only to 346 grs. A ſimilar objection may be made to the 127 grs. ſet down as dry cauſtic ſoda mixed with muriated ſoda. Mr. K. ſays, "I obtained "127 grs. of a mixture of mineral alkali and "common ſalt;" but this like the former was procured by cryſtallization, and therefore the 127 grs. even if they were pure carbonated ſoda would indicate no more than 28 grs. of pure ſoda.

Kelp is made of what is vulgarly called ſea-weed or ſea wrack (whence the French term *ſoude de vareck*) that is of ſuch of the leafy fuci, principally the *veſiculoſus* and *ſerratus*, as grow on rocks in the ſea between the high and the low-water mark. The moſt favourable ſituation for theſe plants is a ſheltered bay full of calcareous rocks: for limeſtone is not only more favourable to the growth of theſe fuci than any other kind of ſtone, but from its lying generally in nearly horrizontal beds is more acceſſible at low-water than thoſe rocks which affect a more vertical inclination, and therefore form narrow ridges. The ſeaſon for gathering the plants is from May to Auguſt. On the Britiſh coaſts they are cut with a ſcythe as cloſe to the rock as poſſible, and then bound up into large bundles, which being faſtened to one end of a long rope, the other extremity of it is tied to a boat, and thus the labour of two or three men is capable of towing ſeveral tons weight to the ſhore. The practice of cutting the ſtems is however by no means ſo judicious as the French method of tearing them up by the roots with inſtruments like rakes; for it has been clearly ſhown[h] that the ſtems when once cut never throw out any more leaves, and the root being a long time in decaying, occupies unprofitably the ſpace which otherwiſe would be filled by young plants. The large bundles when landed are to be opened and their contents ſpread thinly on the ſhore to dry, turning them from time to time, leſt they ſhould ferment, by which both the quantity and quality of the kelp would be greatly deteriorated. The ware when dry ſhould be ſtacked ſecure from rain for a few weeks till it becomes covered with a white ſaline efflorescence, and then it is ready to be burnt. The furnace employed for this purpoſe uſed to be, and in many parts ſtill is, nothing but a round pit three or four feet deep, and ſeven or eight feet acroſs, lined with ſtones: the more ſkilful kelp-burners however make uſe of a kiln of the following conſtruction.[i] It is built of ſtone in the ſhape of a long open coffer, being 28 inches wide in the clear, about 2½ feet high, and from 8 to 18 feet long. The bottom of the kiln being covered with bruſh-wood or heath, a thin ſtratum of the dried ware is ſhaken lightly upon it, and fire is applied to the leeward end of the kiln. It muſt now be gradually ſupplied with freſh ware thrown lightly on wherever the combuſtion reaches the ſurface: if the weather is perfectly calm no further precautions are required than to take care that the fire is not ſtifled, but if it blows ever ſo little the windward ſide of the kiln muſt be covered with ſods, and even both ſides if the weather is at all boiſterous. When all the ware has been thrown on that is intended to be uſed at one time, care muſt ſtill be taken to cover every ſpot where the fire reaches the ſurface with a little of the charred, or leaſt burnt part, laid lightly on by means of a fork. After a time that part of the maſs which is neareſt to the ſides is ſeen to ſoften or melt, and now begins the moſt critical part of the whole proceſs. An iron bar previouſly heated is to be introduced among the ſoft matter, which by this means is to be ſlowly ſtirred up and incorporated, adding by degrees ſome of the leſs burnt portions, and in this manner the whole is to be kneaded together till it becomes a paſty ſemi-fluid maſs. It is a matter of conſiderable dexterity ſo to perform this proceſs as to be able to mix the duſt and fragments of a preceding burning with the preſent, without too much cooling the whole. If when this incorporation of the materials is begun the maſs is too hard and dry, by waiting a ſhort time it will be found to have acquired the neceſſary temper, but if it

[h] Mem. des Sciences, 1772. Part ii. p. 70.

[i] Repertory xii. p. 246.

is dry and pulverulent like aſhes, it is expedient to have recourſe to a little common ſalt, which acting as a flux will begin the fuſion; or if the heat is very languid ſome pulverized brimſtone may be made uſe of. When the kelp has been thus prepared and is grown cold, it is broken into large lumps and is fit for ſale. Well made kelp is of a bluiſh grey colour, ſometimes approaching to green; it is of a more or leſs cellular texture, and contains pieces of charcoal inveloped in the maſs: when breathed on it emits a faint ſulphureous odour; to the taſte it is cauſtic and alkaline, mixed with the ſavour of common ſalt. It yields eaſily to the knife, but poſſeſſes a conſiderable degree of toughneſs. If dry it is uſually covered with a white ſaline efflorescence The proportion of pure ſoda which it contains varies, according to Kirwan and Jameſon,[k] from 1.25 to 5. *per cent.* For the analyſis of barilla and kelp the ſame means are to be employed as have been detailed in the preceding article.

Another ſource of carbonated ſoda which we have not yet mentioned, is common ſalt: but the various methods of decompoſing this ſo as to obtain the alkaline baſe, either pure or combined with carbonic acid, belong more properly to Muriat *of Soda*, to which we refer the reader.

Pure carbonated ſoda from whatever ſubſtance, and by whatever means it is procured, is eſſentially the ſame. Its uſual ſtate is that of clear colourleſs cryſtals, in the form of rhomboidal octahedrons, or oblique tetrahedral priſms. To the taſte it is ſweetiſh, cooling, and ſubalkaline. It is ſoluble in 2.½ times its weight of water at 50°, and at a higher heat diſſolves in its water of cryſtallization. By expoſure to the air it effloreſces, and is converted into a white mealy powder, with the loſs of a great part of its water, and this powder when kept for ſome time at a very low red heat concretes into lumps, loſes a ſmall portion of its carbonic acid and all its water, and is then called *deſiccated ſoda*: in preparing this from the cryſtallized carbonat, the ſalt ſhould be merely laid thinly on a plate at ſome diſtance from the fire, till it is completely effloreſced, otherwiſe by too ſudden a heat it will diſſolve in its own water, and then is very troubleſome to manage. The component parts of cryſtallized carbonat of ſoda have been variouſly eſtimated, though the difference has not been very great: we ſhall mention the proportions as given by Bergman, and thoſe adhered to by Mr. Kirwan.[l]

Bergman		Kirw.
22	–	21.58 ſoda
16	–	14.42 carbonic acid
62	–	64. water of cryſtalliz[n]
100.	–	100.00

Soda, however, is capable of combining with a larger proportion of carbonic acid, by diſſolving the cryſtallized carbonat in water, and then throwing in carbonic acid gas: the cryſtals that are now depoſited will be found to contain a conſiderably leſs quantity of water, and their ſweetiſh ſubalkaline flavour will be exchanged for a cooling ſaline one; ſo that in this ſtate it reſembles the trona. It has not, however, been analyzed with ſuch accuracy as to enable us to ſtate the proportions of its ingredients.

Carbonated ſoda is decompoſed with abſtraction of its baſe, by almoſt all the other acids, and with abſtraction of its acid by barytes, lime, ſtrontian, and potaſh.

The purpoſes to which carbonated ſoda is applied are in general the ſame as thoſe for which carbonat of potaſh is uſed: the circumſtances that induce the occaſional preference of one to the other, will be mentioned in their proper places, eſpecially in Glass making, Soap making, and Dying.

CARBONAT OF BARYTES.

Under the term Witherite the mineralogical deſcription of the native carbonated barytes will be deſcribed, and the methods of analyſing this compound.

The ſeveral methods of procuring the *artificial* carbonat of barytes are deſcribed at length under the article Barytes.

It will be ſufficient to mention in this place that this carbonat appears by the analyſes of Klaproth and Pelletier to be compoſed (when previouſly dried and ignited for a few minutes in a low red heat) of 22 parts of carbonic acid and 78 parts of barytes, perhaps with a trifling portion of water.

The artificial carbonat is much more readily ſoluble in acids than the native. The muriatic or the nitric, conſiderably diluted, diſſolve it with eaſe, and a copious effervescence.

Barytes has ſo ſtrong an affinity for the carbonic acid that barytic water becomes covered with a pellicle of regenerated carbonat inſtantly on expoſure to air, and breathing through it renders it turbid and milky almoſt immediately. The ſame effect takes place with lime-water, but with leſs rapidity.

[k] Mineralogy of Shetland, p. 193.

[l] On Mineral Waters, Table iv.

This carbonat is ſcarcely in any degree ſoluble in water, but when in very fine powder and diffuſed through water, if a ſtream of carbonic acid is ſent through, the water then diſſolves, according to Fourcroy, about $\frac{1}{1000}$ of its weight. The carbonat is not cryſtalizable from this ſolution. By expoſure to the air the exceſs of carbonic acid flies off, and the carbonat of barytes is again precipitated.

CARBONAT OF STRONTIAN.

As in the former article, the methods of procuring this ſubſtance artificially from the ſulphat of ſtrontian are deſcribed under the earth itſelf. (See STRONTIAN.) The analyſis and properties of the native carbonat of ſtrontian belong to the article STRONTIANITE.

Carbonat of ſtrontian dried and gently ignited is compoſed, according to Klaproth, of about 30 parts of carbonic acid with 70 of ſtrontian. Nearly the ſame obſervations apply to this carbonat, as mentioned in the former article, but the affinity for carbonic acid is not ſo ſtrong, and it diſſolves ſomewhat more eaſily.

CARBONAT OF LIME.

Under the article LIMESTONE moſt of the very important natural varieties of this carbonat, with the mode of analyzing, will be deſcribed: and under LIME, the method of freeing theſe earthy ſubſtances from their carbonic acid.

Carbonat of lime is readily prepared artificially by adding a carbonated alkali to the muriat, nitrat, or any other calcareous ſalt. Carbonated ammonia is beſt to obtain it in perfect purity, as all the laſt portions of adhering alkali are totally expelled by drying. When pure, and quite dry, after gentle ignition in a heat barely red for about ten minutes, this carbonat conſiſts ſimply of 45 per cent. of carbonic acid and 55 of lime, which numbers may be conveniently aſſumed in all analyſes. None of the carbonic acid properly belonging to the earthy carbonat is expelled in a heat below thorough redneſs.

Carbonat of lime is ſcarcely in any ſenſible degree ſoluble in pure water, but with an exceſs of carbonic acid it diſſolves in water without difficulty. Thus if carbonated water (or water holding carbonic acid in ſolution) be added in ſmall quantity to lime-water, an inſtant milkineſs enſues, and a precipitate of carbonat of lime; but if an exceſs of carbonated water be added, the mixture again becomes clear by a ſolution of the carbonat of lime in the exceſs of carbonic acid. By far the greater number of natural waters coming immediately from the earth, ſuch as pump—well—mineral waters, hold in ſolution ſome carbonat of lime, and hence they become turbid by boiling, the heat expelling the exceſs of carbonic acid that held the earthy carbonat in ſolution.

Theſe ſolutions of any of the carbonated earths in carbonic acid, give apparently oppoſite indications by the coloured teſts. Paper ſtained red with Brazil wood is turned blue by all the alkalies, and alſo by the carbonated earths. Hence in the above ſolution this change of colour takes place on account of the carbonated earth. On the other hand the purple of litmus is changed to red by acids, and on account of the exceſs of carbonic acid this ſolution alſo reddens litmus-paper. [a]

From the experiments of many accurate analyſts compared by Mr. Kirwan, [b] it appears that the quantity of carbonic acid neceſſary to hold carbonat of lime in ſolution, is inverſely in proportion to the water with which it is mixed, as indeed might be expected, ſince pure water muſt have ſome, though a hardly appretiable action on carbonat of lime independant of any exceſs of carbonic acid. Where the proportion of water to carbonated lime is very great, as for example, about 12000 to 1., the weight of the exceſs of carbonic acid neceſſary for ſolution is only about half that of the carbonat; and in all caſes, however ſmall the quantity of water, carbonated lime is ſoluble therein with the half of its own weight of carbonic acid.

CARBONAT OF MAGNESIA.

This earthy ſalt is not found native, except largely admixed with carbonat of lime in ſeveral of the limeſtones, and in ſolution in many natural waters.

The artificial carbonated magneſia (the common magneſia, or *magneſia alba* of the ſhops,) is prepared by decompoſing the ſulphat of magneſia or Epſom ſalt with common carbonat of potaſh. To ſucceed perfectly in this preparation ſeveral precautions are requiſite. The following is the proceſs uſually given. Take a pound of ſulphat of magneſia diſſolved in about five pints of water, add this to a pound of good purified pearlaſh, or prepared carbonated potaſh, diſſolved in a like quantity of water, and boil them for ſome minutes. A copious white precipitate is produced on the moment of mixture, which renders the whole maſs extremely thick. Strain it while hot through linen (not paper) and waſh the precipitate left on the ſtrainer by repeated affuſions of a very large quantity of boiling water, till it comes away taſteleſs. The pre-

[a] Bergman.

[b] On Mineral Waters.

cipitate gently dried becomes a perfectly white extremely light tasteless powder, which is common magnesia.

A double decomposition takes place in this process, the sulphuric acid quitting the sulphat of magnesia to unite with the potash, and the magnesia uniting with the carbonic acid of the alkali employed. The sulphat of potash being a salt of very sparing solubility in water, renders it necessary to wash the precipitate so abundantly. The drying of the carbonat of magnesia is tedious, for being excessively light and spungy, it retains a large portion of water, which cannot be separated by filtration. In the manufacture in the large way, the paste of magnesia and water is spread on slabs of chalk, which absorbs the water eagerly and much hastens the drying.

Common carbonat of magnesia consists of carbonic acid, water and magnesia in somewhat varying proportions. By being calcined for some time in a red heat, both the water and carbonic acid are expelled, and the entire loss by calcination is on an average about 55 per cent. On the other hand, this carbonat when added to an acid, effervesces violently, but only parts with its carbonic acid in the effervescence, and this loss is about 34 per cent, consequently the constituent parts of 100 parts of the common carbonat of magnesia will be, when dried in a gentle heat,

Magnesia - - - - -	45
Carbonic acid - - -	34
Water - - - - - -	21
	100

The quantity of alkali commonly used in obtaining magnesia is more than is necessary to decompose the magnesian sulphat, and probably one-fourth or one-fifth less would be sufficient.

Common magnesia is scarcely at all soluble in pure water, but with an additional quantity of carbonic acid its solubility increases largely. Hence in making common magnesia it is advisable to boil the ingredients on mixture, by which a considerable quantity of loosely combined carbonic acid is expelled, which otherwise would unite with part of the magnesia, render it soluble in water, and it would be carried away in the washings. Hence the more the alkali employed is saturated with carbonic acid (beyond the exact dose necessary for the precipitated magnesia) the less will be the product left on the filter, unless the boiling be continued a longer time.

This leads to the other distinct species of solid carbonat of magnesia, namely the *crystallized*, or that which is saturated with carbonic acid. It may be prepared in several methods. If carbonated alkali be mixed with sulphat of magnesia, *without heat*, and the mixture left to spontaneous evaporation, small long four-sided prismatic crystals of carbonated magnesia will be deposited. A neater and better way of procuring them is the following. Pass a stream of carbonic acid for some time through water, in which common carbonated magnesia is suspended. The agitation occasioned by the bubbles of gas will prevent the magnesia from entirely subsiding, and it will absorb much of the carbonic acid and dissolve in the water. Decant the clear liquor, and suffer it to evaporate in a heat not exceeding that of a warm room. After a while the carbonated magnesia will separate in crystals. This crystallized salt is composed of about

Magnesia - - - - -	25
Carbonic acid - - -	50
Water - - - - - -	25
	100

It is soluble in 48 times its weight of cold water, and in much less when the water also has an excess of carbonic acid.

Carbonated magnesia in any state is decomposed readily and compleatly by potash, soda, lime, barytes and strontian; the carbonic acid uniting with these substances and leaving the magnesia pure. It is also decomposed by all the salts with the basis of barytes, strontian, and lime. Hence a common caution in preparing magnesia, to wash the precipitate with water as pure as possible and free from calcareous salts; for as most spring-waters contain some sulphat of lime, this salt is decomposed by the carbonat of magnesia, and carbonat of lime is formed, which mixes with the magnesia. This is of little importance medicinally when the magnesia is used in its common state, but after calcination the earth contains a small portion of quick-lime, the effect of which might be felt in large doses.

Ammonia and magnesia appear to have very nearly equal affinities for carbonic acid, and hence it is that either of the two will only partially decompose the saturated carbonat of the other. Thus if ammonia is added to crystallized carbonat of magnesia in solution, the precipitate is not pure magnesia (which it would be with the other alkalies) but the sub-carbonat, or common magnesia alba, and vice versa if pure mag-

neſia be added to the carbonated ammonia, the ſub-carbonat of magneſia is equally produced. In either caſe alſo a part of the ammonia unites with the magneſia, according to Fourcroy, forming a triple ſalt, the *ammoniaco-magneſian carbonat*. The ſame triple ſalt alſo is formed by adding the compound muriat of ammonia with magneſia to carbonat of potaſh or ſoda. The properties of this triple ſalt are not well eſtabliſhed, but its ſuppoſed formation in the above circumſtances correſponds ſufficiently well with the known tendency of ammonia to ſuch triple combinations.

Magneſia is only uſed in medicine.

CARBONAT *of Alumine, Glycine, Zircon*, &c. For the remaining earthy carbonats ſee the reſpective earths.

CARBONATS *Metallic*. See the reſpective metals.

CARBUNCLE. See SPINELL.

CARMINE is a beautiful red precipitate of the colouring matter of COCHINEAL (which ſee).

CARNELIAN. See CHALCEDONY.

CARTHAMUS. See SAFFLOWER.

CARTILAGE. This organ which appears to hold ſomewhat of an intermediate ſtate between ligament and bone appears, according to Mr. Hatchett's reſearches to conſiſt chiefly of condenſed albumen.

Some parts, ſuch as the joinings of the ribs, remain cartilaginous through life; in others the cartilage is the firſt rudiment of bone, that which determines its ſhape and poſition, and it becomes ſolid bone by the gradual depoſition of oſſeous matter. Theſe may be again ſeparated in a great meaſure by acids which diſſolve the bone and leave the cartilage. See BONE and ALBUMEN.

CASSIUS, *Powder of*, is a beautiful precipitate formed by immerſing tin in a ſolution of gold, or by mixing the nitro-muriats of each metal. It is uſed to give the fineſt ruby colour to GLASS. See alſo GOLD.

CATECHU or TERRA JAPONICA.

This ſubſtance, concerning the origin of which there was formerly much doubt, is an inſpiſſated extract prepared in ſeveral parts of India, from a ſpecies of Mimoſa, by decoction of the wood and evaporation to dryneſs. The tree is called in the Bahar province *Coira*, and the extract has the ſeveral names of *catechu, cutch* or *cachou*.

It is thus prepared, according to Mr. Kerr, an eye-witneſs.[a] After felling the trees the manufacturer cuts off all the exterior white part of the wood, which is rejected. The inner wood which is red, and from which alone the extract is prepared, is cut into chips and boiled with water till half is evaporated. This ſtrong decoction is then poured off without ſtraining, into a ſhallow earthen pot and evaporated to one-third by fuel, after which the thorough drying is compleated by the heat of the ſun, the thickened extract being ſpread thin on a mat and expoſed to the air. In this ſimple method is the catechu prepared, but it is often mixed accidentally or fraudulently with ſand or other earthy impurities, ſometimes to the amount of one-eighth of the whole, as appears on analyſis.[b]

There are two varieties of catechu brought to this country, from Bengal and from Bombay, but differing very ſlightly in chemical qualities.

Catechu is of a red brown colour, uniform in texture, brittle and friable, and without ſmell. Its ſpecific gravity from 1.28 to 1.39. The taſte is ſtrongly aſtringent, and at firſt ſomewhat bitter, but afterwards leaves a permanent and agreeable ſweetneſs. It diſſolves ſlowly and totally in the mouth, the earthy impurities excepted.

Catechu is important in a chemical point of view, from the unuſually large quantity of tannin which it has lately been found to contain, and which therefore promiſes to render it uſeful in the preparation of leather. See TANNIN.

By the analyſis of Mr. Davy,[c] at the ſuggeſtion of Sir J. Banks, it appears that there is very little difference between the two ſpecies, and therefore the deſcription of one will ſerve for both.

Catechu is almoſt totally ſoluble in hot water. The ſolution is of a deep red-brown, and ſlightly reddens litmus. By long decoction a ſolution is made, which yields by evaporation as much as $\frac{1}{4}$ of its weight of ſolid matter.

With chemical reagents nearly the ſame effects were produced as when the ſame reagents are added to infuſion of GALLS, and will be mentioned under that article. In particular the preſence both of the gallic acid and of tannin were fully aſcertained, the former among other teſts by the black produced by ſulphat of iron, and the latter by the copious precipitate with animal gelly.

Beſides tannin and gallic acid, catechu contains a peculiar extract, and alſo a ſubſtance reſembling mucilage. The latter is left nearly pure after the action of alcohol, which readily diſſolves all the reſt. It ſcarcely differs from common gum mucilage. The extractive matter

[a] Medical Obſervations, Vol. 5. [b] Lewis's Mat. Med. [c] Phil. Tranſ. for 1803.

is ſoluble in water, but much leſs eaſily than the tannin, and hence if the catechu in fine powder be repeatedly and for a ſhort time waſhed with water, all the tannin is diſſolved (which is known by no longer precipitating the ſolution of glue) and alſo moſt of the mucilage, and the reſidue is a pale red extract, only ſlightly aſtringent, but conſiderably ſweet when chewed. It diſſolves both in water and alcohol, acquiring a deeper colour by expoſure to air.

Catechu therefore conſiſts chiefly of—1ſt. a very large portion of tannin, to which it owes its aſtringency, and the very great powers which it poſſeſſes as a material for tanning leather: 2d. of a peculiar extract, in which reſides the ſweetneſs of taſte for which this extract is valued in the Eaſt: and 3d. a ſmall portion of mucilage, inert and inſipid. Mr. Davy found that 200 grains of the Bombay catechu contained 109 grains of tannin, 68 of extract, and 13 of mucilage, with 10 of earthy reſidue. The ſame quantity of the Bengal catechu gave of the ſame ingredients 97 grains, 73, 16, and 14.

Catechu is uſed in the Eaſt, as it is ſaid, for many proceſſes of dyeing, and would doubtleſs anſwer in many caſes where galls are now uſed. But its chief conſumption is as an ingredient in the betel compoſition, which is ſo univerſally chewed. It is uſed in this country only in medicine, as a very valuable aſtringent, but its tanning powers deſerve farther trial.

CAT's-EYE. See KATZEN-AUGEN.

CAUSTICITY. *Aetzbarkeit*, Germ.

A ſubſtance is uſually ſaid to be cauſtic when it produces the ſame effect to the tongue as that of actual fire, that is, an immediate ſenſation of burning, followed with a ſlight diſorganization of the ſurface actually in contact. Thus the alkalies are called *cauſtic* when deprived of carbonic acid, becauſe, when at all concentrated, they then burn and bliſter the tongue almoſt inſtantly.

Cauſtic ſubſtances are alſo generally *corroſive*, or ſuch as act upon organized matter and decompoſe it with great rapidity.

The term cauſtic prefixed to the alkalies and earths to diſtinguiſh the pure or de-carbonated ſtate, is omitted in the modern nomenclature, being rendered unneceſſary by the uſe of the term *carbonat*: thus to the terms *cauſtic potaſh* and *mild potaſh* are ſubſtituted thoſe of *potaſh* and *carbonat of potaſh* reſpectively. Some confuſion ſtill ariſes occaſionally from this change, the term *ſoda* for example, meaning in chemical language *pure or cauſtic ſoda*, and in commerce and common uſe meaning the *mild, carbonat of ſoda*. In this work where the carbonat is meant, it is always ſo expreſſed.

CAUSTIC *Lunar* is the nitrat of SILVER melted and caſt into cylindrical pieces about the ſize of common ſlate-pencils, for the uſe of ſurgeons.

CEMENTATION. *Camentiren*, Germ.

This term is applied to a proceſs in the dry way ſimilar to digeſtion in the moiſt, and means the expoſure of any ſubſtance to a regular furnace-heat in a crucible, ſtratified, or otherwiſe covered, with ſome kind of powder, which is intended to produce a chemical change. Thus iron bars are converted into ſteel by being cemented with a powder of bone-aſh and other materials: copper into braſs by cementation with a powder of calamine and charcoal, and the like. The powder is in this caſe called *Cement-powder*.

CEMENT-COPPER. The copper procured from the ſulphat by precipitation with iron is ſo called. See COPPER.

CEMENTS and LUTES. Under this article may be mentioned the receipts for preparing ſome of the moſt uſeful ſubſtances of this kind that are required in common chemical operations.

The uſes of lutes and cements are, either to cloſe the joinings of chemical veſſels to prevent the eſcape of vapours and gaſſes during the proceſſes of diſtillation, ſublimation and the like: or to protect veſſels from the action of the fire which might crack, or fuſe, or calcine them: or ſometimes to repair flaws and cracks, and for a variety of other ſmaller purpoſes.

The ſubject of *calcareous cements*, ſuch as mortar, tarras, and other ſubſtances uſed to cloſe the joinings of bricks or ſtones in buildings, will be mentioned in the following article.

When a lute is applied over the whole ſurface of a veſſel (as to a glaſs retort when it is intended to be heated red-hot) the proceſs is termed *lorication* or *coating*. Iron furnaces are alſo *lined* or *coated* on the inſide with earth to prevent the iron from being deſtroyed by the conſtant action of the fire.

From the vaſt variety of receipts for lutes and cements of different kinds the following may be ſelected, which will anſwer moſt of the purpoſes of the experimental chemiſt.

To prevent the eſcape of the vapors of water, ſpirit, and liquors not corroſive, the ſimple application of ſlips of moiſtened bladder will anſwer very well for glaſs, and paper with good paſte for metal. Bladder to be very adheſive ſhould be ſoaked ſome time in water, moderately warm, till it feels clammy, it then ſticks very

well. If ſmeared with white of egg inſtead of water, it adheres ſtill cloſer.

Another very convenient lute is linſeed meal moiſtened with water to a proper conſiſtence, well beaten, and applied pretty thick over the joinings of the veſſels. This immediately renders them tight, and the lute in ſome hours dries to a hard maſs. Almond paſte will anſwer the ſame purpoſe.

The uſe of the above lute is ſo extenſive that no other is required in cloſing glaſs veſſels in preparing all common diſtilled liquors, and it will even keep in ammonia and acid gaſſes for a longer time than is required for moſt experimental purpoſes. It begins to ſcorch and ſpoil at a heat much above boiling, and therefore will not do as a *fire lute*. It is ſtill firmer and dries ſooner when made up with milk, or lime-water, or weak glue.

A number of very cohefive cements impervious to water, and moſt liquids, and vapors, and extremely hard when once ſolidified, are made by the union of quick-lime with many of the vegetable or animal mucilaginous liquors. The variety of theſe is endleſs. We may firſt mention the following as it has been extenſively employed by chemiſts for centuries. Take ſome whites of eggs with as much water, beat them well together, and ſprinkle in ſufficient ſlacked lime to make up the whole to the conſiſtence of thin paſte. The lime ſhould be ſlacked by being once dipped in water, and then ſuffered to fall into powder, which it will do ſpeedily with great emiſſion of heat, if well burnt. This cement ſhould be ſpread on ſlips of cloth and applied immediately, as it hardens or *ſets* very ſpeedily. While hardening, it may be of uſe to ſprinkle over it ſome of the lime in fine powder. This cement is often more ſimply, and as conveniently managed by ſmearing ſlips of linen on both ſides with white of egg, and, when applied to the joining of the veſſel, ſhaking ſome powdered lime over it. It then dries very ſpeedily.

Another lute of the ſame kind, and equally good, is made by uſing a ſtrong ſolution of glue to the lime, inſtead of the white of egg. It ſets equally ſoon, and becomes very hard. A mixture of liquid glue, white of egg, and lime, makes the *lut d'ane*, which is ſo firm that broken veſſels united with it are almoſt as ſtrong as when ſound. None of theſe lutes however will enable theſe veſſels to hold liquids for any great length of time. Milk or ſtarch with lime make a good but leſs firm lute.

A very firm and ſingular lute of this kind is made by rubbing down ſome of the pooreſt ſkimmed-milk cheeſe with water to the conſiſtence of thick ſoup, and then adding lime and applying as above. It anſwers extremely well. Lime and blood with a ſmall quantity of brick-duſt or broken pottery ſtirred in is uſed in ſome places as a very good water-cement for cellars and places liable to damp.

Paris plaſter mixed with egg, milk, glue, ſtarch, or any mucilaginous liquor, alſo makes a good lute.

Some artiſts mix other earths with the above materials. Thus a very good cement is made with equal parts of clay and lime, about $\frac{1}{3}$ of flour and white of egg; or as is uſed by many of the aqua-fortis makers, a mixture of colcothar, lime, and white of egg.

All the above-mentioned cements with lime become very hard by drying, inſomuch that they cannot be ſeparated from glaſs veſſels without the help of a ſharp knife and ſome violence, and hence delicate veſſels and long thin tubes cemented with it are apt to break when the apparatus is taken down, and ſometimes even by the mere force of contraction in ſetting. It is a great advantage however that they may be applied immediately to any accidental crack or failure of the lute already on, notwithſtanding a ſtream of vapour is burſting through, and in large diſtillations it is of advantage always to have ſome of the materials at hand.

Theſe lutes will not confine very corroſive acid vapours perfectly for a great length of time, but will anſwer for other purpoſes, particularly where a complicated apparatus is to be kept ſteadily united and air-tight. They will bear nearly a red-heat without material alteration.

Another kind of lute which is the moſt perfect for confining acid vapours for any length of time, and which never hardens to an inconvenient degree is the *fat lute* as it is called. This is made by taking any quantity of good clay, tobacco-pipe clay for example, thoroughly dry, but not burnt, powdering it in an iron mortar, mixing it gradually with *drying* linſeed oil, and beating them for a long time to the conſiſtence of thick paſte. Much manual labour is required, and it ſhould be continued till the maſs no longer adheres to the peſtle. Then make the edges of the glaſs or other veſſels where it is to be uſed perfectly dry, and apply the lute carefully, and it will ſtand the longeſt proceſs without failing. This grows firm enough to retain its place and to hold the veſſels together, but may readily be ſeparated by a knife. This lute much improves in adheſive-

neſs by long keeping, which ſhould be in a covered pan in a cool cellar. When wanted, it regains ſufficient ductility merely by being beaten for a minute or two, or by the help of a few drops more of the oil. Good glaziers putty, which is made of chalk beat up with drying linſeed oil, much reſembles the fat lute in quality.

Another ſpecies of lute is that which is commonly applied round glaſs retorts when diſtillation with a full red heat is wanted to protect them from the ſudden action of the fire, and to give them firmneſs, and enable them to bear this heat without flattening or falling together when red-hot, or melting with the fuel. A glaſs veſſel ſo prepared with a thick earthen coating may be conſidered as an earthen veſſel glazed on the inſide. The ſubſtance uſed is a mixture of ſand with juſt ſufficient clay to make it adhere together, beat up with ſome kind of fibrous matter ſo as mechanically to encreaſe the tenacity. A natural earthy mixture of the kind is Windſor loam, or an equally good one may be formed with coarſe ſand and clay or better with fragments of pottery coarſely ground (the fine part being ſeparated by ſifting and rejected) mixed with more or leſs clay according to the quality, ſo that it will juſt mould together when wet. For the fibrous matter, ſome uſe horſe-dung, which appears the beſt, others, chopped ſtraw or chaff, others, chopped horſe and cow hair or tow, all of which anſwer the ſame purpoſe. A ſmall quantity of theſe will ſuffice. Beaumé recommends about an ounce of cow's hair to five pounds of the earthy mixture. A good deal of water ſhould be added when the materials are mixed, and much manual labour is required to diffuſe the hair equally through the mixture. To apply it to a glaſs veſſel, a retort, for example, take a ſufficient quantity of the lute, ſpread it out flat on a table, lay the bottom of the retort on the middle of the maſs, and then turn up the edges of the flat cake, and bring it over the reſt of the glaſs, preſſing it down with the fingers till it applies uniformly and cloſely. By this method the lute is without ſeam, and is much more likely to dry in the fire without cracking. Or elſe, bring the lute with ſufficient water to the conſiſtence of thick ſoup, dip the retort in, and it will come out thinly coated. Turn it round before the fire, and when dry dip it again in the lute to give a ſecond coating, and ſo on to the required thickneſs, which may be from $\frac{1}{4}$ to $\frac{1}{2}$ an inch. A lute ſimilar to this is uſed as a lining to iron furnaces to confine the fire and prevent the iron from conſuming by the conſtant heat. This lute is juſt ſo fuſible as to begin to agglutinate in a full red heat, and hence, if it remains ſound till thus hot, it will form an impenetrable coating to the glaſs within, from which it cannot afterwards be detached. The covers of crucibles and other veſſels intended to bear fire may be luted with this earthy mixture. It is rendered ſtill leſs liable to crack on the firſt heating, if, when thoroughly dry, it is ſmeared with linſeed oil.

Sometimes however a ſtill more fuſible compound is wanted, particularly where very volatile and penetrating ſubſtances are diſtilled from an earthen veſſel. Theſe veſſels are neceſſarily porous to a certain degree, independent of any caſual cracks, from which the larger earthen veſſels are ſeldom entirely free. When phoſphorus (for example) is prepared by ſtrongly heating charcoal and phoſphoric acid in one of theſe retorts, the vapour of the phoſphorus penetrates through the pores when thoroughly red hot, and much of it is loſt. Nor will the laſt-mentioned luting entirely prevent this, ſo that it is a great ſaving to cover the retort firſt with a thin coat of a fuſible glazing, which will melt on the ſurface as ſoon as red-hot, and cloſe every opening. This glazing may be made by a variety of fluxes added to the proper doſe of clay and earth, and mixed into a thin paſte, and applied to the retort with a bruſh. The following management is recommended by Mr. Willis,[d] a practical chemiſt, in diſtillation with large earthen retorts. Diſſolve one ounce of borax in half a pint of boiling water, and add as much ſlacked lime as will make it into a thin paſte. Spread it over the retort with a bruſh, and when dry apply over the whole a lute of ſlacked lime and linſeed oil beaten till it is perfectly plaſtic. This becomes dry in a day or two, and is then fit for uſe. Stone retorts may thus be uſed ſeveral times with ſafety (always renewing the oil and lime lute) whereas in the common way, and even with the clay and hair lute they generally crack when cooling, or on being heated a ſecond time. If during the operation the retort ſhould crack, Mr. W. adviſes to ſpread ſome of the oil compoſition thickly on the part, and ſprinkle ſome ſlacked lime over the whole, which will prevent the further eſcape even of the penetrating vapour of phoſphorus, and may be ſafely applied even when the retort is red-hot. When prepared ſomewhat thicker

[d] Repertory, vol. i.

it is very proper as a general lute for a great variety of purpoſes, and will never harden ſo as to break the veſſel.

Often a fire lute is required to join the covers to crucibles, or for ſimilar purpoſes, ſo as to keep them air-tight when hot. A very valuable compoſition of the kind is made of glaſs of borax, brick-duſt, and clay, finely powdered together and mixed with a little water when uſed. No very great nicety is required in the proportions, but about a tenth of borax is quite ſufficient to bring the earths to that ſtate of ſemi-vitrification which is deſired. Litharge may alſo be uſed inſtead of borax, but the latter is by far the beſt, as it promotes that thin ſpreading fuſion which is beſt calculated to be equally applied over an uneven ſurface, and beſides, if a portion of the litharge-lute were to drop into the crucible it might poſſibly be reduced, and lead introduced into the reſults of the experiment.

A cement ſaid to be uſeful to ſtop cracks of iron veſſels intended to be ſtrongly heated, is made of 6 parts of clay, 1 of iron filings, and linſeed oil enough for mixture.

Another ſpecies of cement is what is termed by the French *Maſtich chaud*, and conſiſts of different kinds of oily and reſinous ſubſtances, liquid when hot, and which become more or leſs ſolid by cooling. They are uſeful for a variety of miſcellaneous purpoſes, for experiments with gaſſes over water or mercury, and others where only a very moderate warmth is uſed, and where it is of importance to keep out air and water. Theſe will alſo confine acid vapors, but not the vapors of alcohol, turpentine, or eſſential oils, which diſſolve moſt reſinous ſubſtances. Moſt of them will ſtick very well to glaſs. Common ſealing-wax is one of the moſt uſeful of theſe cements. A cheaper and leſs brittle cement is made ſimply by melting bees wax with about one-eighth of common turpentine. This may be made up into ſticks to be uſed when wanted, being firſt melted or ſpread evenly with a hot iron. A greater portion of turpentine renders this lute ſofter, and more fuſible, but ſomewhat pliable.

A very firm cement is made by 4 parts of roſin, 1 of bees wax, and when melted, 1 part of fine brick duſt ſtirred in. This adheres with extreme firmneſs. Table knives are cemented to their handles by this mixture, and turners uſe a ſimilar compoſition in ſome fine works to fix them to the lathe.

Chaptal found after many trials that the penetrating vapours of ſulphureous acid in the manufacture of alum were completely confined in a wooden chamber, lined very carefully with a mixture of equal parts of pitch, turpentine, and wax, boiled till all the eſſential oil was diſſipated (which was known by the ceſſation of the bubbles) applied melted to the wood, and ſpread with a hot trowel over the joints. Vintners ſtop leaks in their caſks with melted ſuet[a] rubbed over, when cooling, with ſifted wood-aſhes, or previouſly mixed with the aſhes in melting.

The uſe of gum arabic diſſolved in water for cementing paper labels to bottles, and a great variety of miſcellaneous purpoſes is known to every one. A ſtill better cement for the ſame uſes is iſinglaſs diſſolved in vinegar to a pretty thick conſiſtence when warm. This congeals on cooling, and before it is uſed it ſhould be gently warmed.

Many of the varniſhes and oil paints are employed in rendering veſſels air and water tight. Thus when canvas bags are faſtened to a ſtop-cock tube for air-holders, the joining is made perfectly tight by tying over it ſlips of cloth or bladder ſoaked in ſpirit varniſh.

The following cement is ſaid to be very uſeful in joining together glaſs or ſteel. Take of maſtich five or ſix bits as big as peas, diſſolve in as much alcohol as will render them liquid. In another veſſel diſſolve as much iſinglaſs (previouſly ſoaked in water) in brandy or rum as will make two ounces by meaſure of a ſtrong glue; warm it and incorporate with it, by rubbing, two or three ſmall bits of galbanum or ammoniacum, and then the maſtich ſolution. Keep the cement in a bottle well ſtopped, and gently warm it before uſe.

Thoſe fuſible metallic compounds uſed to unite pieces of metal, form another totally diſtinct ſpecies of cements. Theſe are termed Solders, under which they will be deſcribed.

Some inconveniences occaſionally attend the uſe of theſe lutes in chemical operations. The application of them takes up time and requires a little manual dexterity, which can only be learned by practice. In ſome nice experiments of reſearch, where ſubſtances are decompoſed by diſtillation, and all the products are to be analyzed, the lute itſelf is often ſlightly corroded or otherwiſe acted on, and introduces ſome confuſion in the reſult. It is partly on this account, and chiefly to ſave trouble to the chemiſt, that the practice of cloſely fitting glaſs veſſels by grinding is ſo much more uſed at preſent than formerly; but this is always expenſive,

[a] Encycl. Arts & Metiers.

and in complicated apparatus much endangers the veſſels by the partial ſtreſs on the parts that cloſely fit.

It may be added, that the modern uſe of Woulfe's apparatus, or ſimilar contrivances, ſo completely takes away the preſſure of expanſive vapours in all diſtillations, that in many inſtances very ſimple lutes will anſwer now, where formerly it was neceſſary to render the joinings of veſſels as firm as the veſſels themſelves. But the proper application of all theſe kinds of cements is of great importance to the practical chemiſt to prevent continual loſſes and diſappointments.

CEMENTS CALCAREOUS.

In this article it is propoſed to give an account of the various cements uſed in building, into which lime enters as an eſſential conſtituent part, and in order to treat the ſubject with a degree of clearneſs in ſome meaſure correſponding to its importance, it will be adviſable to arrange every kind of calcareous cement under one or other of the following three diviſions, firſt, ſimple calcareous cement: ſecondly, water cements: thirdly, maſtichs or maltha.

§ 1. *Simple Calcareous Cements.*

This ſection includes thoſe kinds of mortar which are employed in buildings on land, and generally conſiſt of lime, ſand, and freſh water.

The various kinds of marble, chalk, and lime ſtone, as far as regards their uſe in cements, may be divided into two ſpecies; the firſt being pure, or nearly pure carbonat of lime, the ſecond containing beſides from $\frac{1}{20}$ to $\frac{1}{12}$ of clay and oxyd of iron. Previous to burning or calcination, there are no external characters by which the ſimple limeſtones can be diſtinguiſhed from the argillo-ferruginous ones; but the former, whatever may have been their colour in the crude ſtate, become when calcined, of a white colour, while the latter poſſeſs more or leſs of a light ochery tinge. The brown lime is by far the beſt for all kinds of cements, but the white varieties being more abundant, and allowing of a larger proportion of ſand, are generally made uſe of. It was an opinion of the ancients, and is ſtill commonly received among architects, that the hardeſt lime ſtone, *ceteris paribus*, furniſhes the beſt lime; hence marble was conſidered as ſuperior to common limeſtone, and this latter to chalk. The experiments of Mr. Smeaton,[a] however, ſhow that this is entirely a miſtake, common chalk and the hardeſt Plymouth marble, when ſimilarly treated, affording cements of equal firmneſs.

When carbonated lime has been thoroughly burnt it is deprived of its water, and of all, or nearly all of its carbonic acid; if in this ſtate it is plunged into water, and immediately taken out again, the water which it has abſorbed will occaſion the maſs to crack and become exceſſively hot, and at length to fall into an impalpable powder, much of the water being carried off in the form of ſteam during the proceſs. When lime has been thus ſlacked, if it is beaten up with a little water into a very ſtiff paſte and allowed to dry, it will be found that the white limes, whether from chalk or marble, never acquire any degree of hardneſs, that the brown limes become conſiderably indurated, though not ſo much ſo as when mixed with ſand, and that ſhell lime (procured by calcining ſea-ſhells) concretes into a firm hard cement well qualified for dry building, although it falls to pieces in water.[b]

A proper ſelection of ſand is of great importance in the compoſition of mortar; the ſharper and coarſer it is, the better, both becauſe it requires a ſmaller proportion of lime, which is the moſt coſtly ingredient, and becauſe the mortar thus prepared is ſtronger than when fine grained and round ſand is made uſe of. Sea ſand requires to be well waſhed in freſh water to diſſolve out the ſalt with which it is mixed, otherwiſe the cement, into which it enters, never becomes thoroughly dry and hard. The Roman builders were accuſtomed to allow four parts of coarſe ſharp pit ſand, and only three parts of river or ſea ſand to one of lime.[c] If, however, the cement was required to be very compact, the proportion of lime was increaſed: thus the mortar uſed in conſtructing reſervoirs for water, conſiſted of two parts of the ſtrongeſt lime and five parts of pure and ſharp ſand.[d]

The weakneſs of modern mortar compared to the ancient is a common ſubject of regret, and many ingenious men taking for granted that the proceſs uſed by the Roman architects in preparing their mortar is one of thoſe arts which are now loſt, have employed themſelves in making experiments to recover it inſtead of attending to the directions left us in Pliny and other authors, which when illuſtrated by the actual practice of builders in various parts of Europe, ſeem to leave little or no doubt on the ſubject.

The characteriſtic of all modern artiſts, builders among the reſt, ſeems to be to ſpare their time and labour as much as poſſible, and to increaſe the quantity of the articles they produce

[a] Hiſt. of Eddyſtone Light Houſe. [b] Ibid. [c] Pliny, Hiſt. Nat. Lib. xxxvi. [d] Ibid.

without much regard to their goodneſs; and perhaps there is no manufacture in which this is ſo remarkably exemplified as the preparation of common mortar, eſpecially in London and its neighbourhood.

One radical fault is the uſe of chalk inſtead of ſtone lime, for although chalk when perfectly burnt is equally good as the hardeſt lime, yet it poſſeſſes two capital diſadvantages, firſt, it will fall into a coarſe powder on the application of water, when it is only partially calcined, which ſtone lime will not; and ſecondly, the cores or unburnt lumps may be broken down by a blow with the ſpade, and are therefore very ſeldom rejected as they ought to be. The whiteſt chalk is the worſt of all, both as being the ſofteſt, and as being a *fat* lime, that is, containing no clay and iron, in conſequence of which a larger proportion of ſand may be incorporated with it, and the mortar becomes leſs compact. The yellowiſh grey chalk on the other hand is the beſt, ſince it is ſomewhat harder than the former, and being a *meagre* lime, containing a portion of clay, it will not admit of ſo much ſand. The Dorking lime which is the beſt of thoſe uſed in London, is a chalk lime of this deſcription, and contains about $\frac{1}{17}$ of clay.[c]

Another eſſential fault in London mortar is the bad quality of the ſand with which it is compoſed. This is pit-ſand, but very different from the kind recommended by Pliny and Vitruvius; inſtead of being clean, large-grained, and ſharp, it is of a dirty browniſh grey colour, being ſoiled by a mixture of clay, and is compoſed of ſmall round grains. Its fineneſs and ſmoothneſs cannot be amended, but by waſhing it well in running water the clay might unqueſtionably be got rid of, and this would be no trifling improvement; for Smeaton has ſhown by direct experiment that mortar of the beſt quality when mixed with a ſmall proportion of *unburnt* clay never acquires that hardneſs and dryneſs which without this addition it would ſpeedily have attained.

The method of preparing common mortar is alſo extremely imperfect. The lime being ſlacked by the addition of water, and the unburnt lime being broken down and mixed with the reſt, a large quantity of dirty ſand is added, and the whole being incorporated by means of a ſpade is reckoned to be fit for uſe; thus the principal point in the making of mortar, namely, beating the ingredients together ſo as to mix them thoroughly, is ſlurred over in a haſty careleſs manner, and the reſult, as might be expected, is a crumbling maſs ſcarcely fit for uſe. The Roman builders, on the other hand, after they had mixed together the materials, employing for this purpoſe a ſmaller proportion of water than is cuſtomary at preſent, put the maſs into a large wooden mortar, and beat it till it ceaſed to adhere to the heavy wooden or iron peſtle which was uſed on the occaſion. A practice this which has been long followed by the Dutch with compleat ſucceſs, as will be ſhown in the next ſection, and the high utility of which is alſo proved by Mr. Smeaton, in his hiſtory of Eddyſtone light-houſe.

Freſh made mortar, if kept under ground in conſiderable maſſes, may be preſerved for many months without injury; and the older it is before it is uſed the better, the builder taking the precaution to beat it up afreſh previous to uſing it; for it not only ſets ſooner, but acquires a greater degree of hardneſs, and is leſs apt to crack. Pliny informs us that the ancient Roman laws prohibited builders from uſing mortar that was leſs than three years old, and to this circumſtance he expreſsly attributes the remarkable firmneſs of the oldeſt buildings in the city. A ſimilar law prevailed, and, we believe, ſtill prevails in Vienna, requiring the mortar to be a year old before it is employed. But there is nothing which ſhows in ſo ſtriking a point of view the advantage and neceſſity of beating mortar, and that the effect produced is owing to ſomething more than a mere mechanical mixture of the ingredients, as the preparation of *grout* or liquid mortar. This differs from common mortar only in containing a larger quantity of water, ſo as to be ſufficiently fluid to penetrate the narrow irregular cracks and interſtices of rough ſtone walls, and is generally made by diluting common mortar with water either cold or hot. It not unfrequently happens that this grout refuſes to ſet, and at all times it is a long while in acquiring the proper hardneſs: but if inſtead of common mortar, that which has been long and thoroughly beaten is employed, the grout will ſet in the ſpace of a day, and ſoon after acquire a degree of hardneſs much ſuperior to what is made in the common manner.

§ 2. *Water Cements.*

Although a well made mortar compoſed merely of ſand and lime, if allowed to dry, becomes impervious to water, ſo as to ſerve for the lining of reſervoirs and aqueducts, yet if the circumſtances of the building are ſuch as to render it impracticable to keep out the water

[c] Smeaton.

whether freſh or ſalt a ſufficient length of time, the uſe of common mortar muſt be abandoned; for lime and ſand if mixed together in any proportions, and put while ſoft into water, will in a ſhort time fall to pieces.

Among the nations of antiquity the Romans appear to have been the only people who practiſed building in water, and eſpecially in the ſea, to any great extent. The bay of Baiæ, like our faſhionable watering places, was the ſummer reſort of all the wealthy in Rome, who not content with erecting their villas as near the ſhore as poſſible, were accuſtomed to conſtruct moles, and form ſmall iſlands in the more ſheltered parts of the bay, on which, for the ſake of the grateful coolneſs, they built their ſummer houſes and pavilions. They were enable to build thus ſecurely in the water by the fortunate diſcovery at the neighbouring town of Puteoli of an earthy ſubſtance, which, from this circumſtance, was called *pulvis Puteolanus* (powder of Puteoli). Puteolan powder, or as it is now denominated Puzzolana, is a light, porous, friable mineral of a red colour, and is generally ſuppoſed to derive its origin from concreted volcanic aſhes thrown out from Veſuvius, near to which mountain the town of Puteoli is ſituated: it ſeems to conſiſt of a ferruginous clay baked and calcined by the force of volcanic fire, and when mixed with common mortar, not only enables it to acquire a remarkable hardneſs in the air, but to become as firm as ſtone even under water. The only preparation which Puzzolana undergoes is that of pounding and ſifting, by which it is reduced to a coarſe powder: in this ſtate, being thoroughly beaten up with lime, either with or without ſand, it forms a maſs of remarkable tenacity which ſpeedily ſets under water, and becomes at leaſt as ſtrong as good freeſtone. In the compoſition of water cements it is that the ſuperior efficacy of argillo-ferruginous lime compared with the purer kinds is moſt ſtrikingly manifeſt, and as building in water is generally very expenſive and difficult to repair, every precaution ſhould be taken to ſecure the goodneſs of the cement. In ſituations expoſed to the violent ſhocks of the ſea the difference of expence between the beſt and inferior kinds of mortar is ſo little, compared to the whole coſt and the ſatisfaction of perfect ſecurity that the cement ought to be of the very beſt quality. That which was uſed by Mr. Smeaton, in the conſtruction of Eddyſtone light houſe, was compoſed of equal parts by meaſure of ſlacked Aberthaw lime and Puzzolana; but for works that are leſs expoſed, ſuch as locks and baſons for canals, &c. the proportions of Puzzolana may be conſiderably diminiſhed. A compoſition of this kind which has been found very effectual is 2 buſhels of ſlacked Aberthaw lime, 1 buſhel of Puzzolana, and 3 of clean ſand; the whole being beaten well together with the proper quantity of water will yield 4.67 cubic feet of cement.

The Dutch have practiſed building in water to a greater extent than any other nation of modern Europe, and to them is due the diſcovery of a cement admirably well qualified for this purpoſe, and called tarras or traſs. This is nothing more than wakke or cellular baſalt, and is procured chiefly from Bockenheim, Frankfort on the Maine, and Andernach, whence it is tranſported down the Rhine in large quantities to Holland.[f] It undergoes no further preparation than grinding and ſifting, and being thus reduced to the conſiſtence of coarſe ſand it is beaten up with the blue argillaceous lime from the banks of the Schelde, and thus compoſes the celebrated tarras mortar with which the mounds and other conſtructions for the purpoſe of protecting the lowlands of Holland againſt the ſea are cemented. The ſtrongeſt tarras mortar is compoſed of 2 meaſures of ſlacked lime, and 1 of tarras; another kind almoſt equally good and conſiderably cheaper, is made of two meaſures of ſlacked lime, one of tarras, and 3 of coarſe clean ſand; it requires to be beaten a longer time than the foregoing, and produces $3\frac{1}{2}$ meaſures of excellent mortar. When the building is conſtructed of rough irregular ſtones where cavities and large joints are to be filled up with cement, the pebble mortar may be moſt advantageouſly applied: this was a favourite mode of conſtruction among the Romans, and has been uſed ever ſince their time in thoſe works in which a large quantity of mortar is required. Pebble mortar will be found of ſufficient compactneſs if compoſed of 2 meaſures of ſlacked argillaceous lime, half a meaſure of tarras or puzzolana, 1 meaſure of coarſe ſand, 1 of fine ſand, and 4 of ſmall pebbles ſcreened and waſhed. Although the cellular baſalt is the only kind admitted into the preparation of Dutch tarras, yet it appears from ſome good experiments of Morveau, on the ſubject, that the common compact baſalt if previouſly calcined will anſwer nearly the ſame purpoſe.[g] Great Britain is at a conſiderable annual expence in purchaſing tarras from Holland, it may be worth while therefore to point

[f] Vogel in N. Comm. Gott. iii. p. 51. [g] An. de Chim. xxxvii. p. 253.

out ſome of our domeſtic treaſures of the ſame material. The compact baſalt abounds in all the diſtricts where coal is raiſed, and may therefore be procured eaſily, and calcined with the refuſe coal ſo as to be ſold at a cheap rate: the Calton hill adjoining to Edinburgh conſiſts almoſt entirely of cellular baſalt, and being but a ſhort diſtance from the port of Leith, offers an inexhauſtible abundance at ſmall coſt.

In ſome parts of the Low Countries coal aſhes are ſubſtituted for tarras with very good effect, of which the valuable *cendrée de Tournay* is a ſtriking inſtance. The deep blue argillo-ferruginous lime ſtone of the Schelde is burnt in kilns with a flaty kind of pit coal that is found in the neighbourhood: when the calcination of the lime is compleated, the pieces are taken out, and a conſiderable quantity of duſt and ſmall fragments remain at the bottom of the kiln. This refuſe conſiſts of coal aſh mixed with about $\frac{1}{4}$ of lime duſt, from which the cendrée is thus prepared. About a buſhel of the materials is put in any ſuitable veſſel, and ſprinkled with water juſt ſufficient to ſlack the lime; another buſhel is then treated in the ſame way, and ſo on till the veſſel is filled: in this ſtate it remains ſome weeks, and may be kept for a much longer time if covered with moiſt earth. A ſtrong open trough, containing about two cubic feet, is filled about two-thirds full with the cement in the above ſtate, and by means of a heavy iron peſtle ſuſpended at the end of an elaſtic pole is well beaten for about half an hour; at the end of this time it becomes of the conſiſtence of ſoft mortar, and is then laid in the ſhade from three to ſix days according to the dryneſs of the air; when ſufficiently dry, it is beaten again for half an hour as before, and the oftener it is beaten the better will be the cement; three or four times however are ſufficient to reduce the cement to the conſiſtence of an uniform ſmooth paſte; after this period it is apt to become refractory on account of the evaporation of its water, as no more of this fluid is allowed to enter the compoſition than what was at firſt employed to ſlack the lime. The cement thus prepared is found to poſſeſs the ſingular advantage of uniting in a few minutes ſo firmly to brick or ſtone that ſtill water may be immediately let in upon the work without any inconvenience; and by keeping it dry for 24 hours, it has afterwards nothing to fear from the moſt rapid current.

Somewhat analogous to the preceding is a cement uſed in certain parts of England with advantage, and called aſh-mortar. It is prepared by ſlacking two buſhels of freſh burnt meagre lime, and mixing it accurately with three buſhels of wood-aſhes: the maſs is to lie till it is cold, and is then to be well beaten: in this ſtate it will keep a conſiderable time without injury, and even with advantage, provided it is thoroughly beaten twice or thrice before it is uſed.[1]

The ſcales of black oxyd which are detached by hammering red-hot iron, and are therefore to be procured at the forges and blackſmiths' ſhops, have been long known as an excellent material in water cements, but we believe that Mr. Smeaton was the firſt perſon who made any accurate experiments on their efficacy compared with other ſubſtances. The ſcales being pulverized and ſifted, and incorporated with the lime in the ſame manner as puzzolana, are found to produce a cement equally powerful with puzzolana mortar, if employed in the ſame quantity. Induced by the ſucceſs of theſe experiments, Mr. S. ſubſtituted roaſted iron ore for the ſcales, and found that this alſo gave to mortar the property of ſetting under water: it requires however to be uſed in greater proportions than either tarras or puzzolana: two buſhels of argillaceous lime, two of iron ore, and one of ſand, being mixed with the ſame care as we have already mentioned, produce 3.22 cubic feet of cement fully equal to tarras mortar. If the common white lime is made uſe of, it will be adviſeable to employ equal quantities of all the three ingredients.

Nothing more remains to be ſaid on this part of the ſubject but a few words concerning the choice of the water by which the ſeveral ingredients of the cement are to be mingled together. River or pond water, where it can be had eaſily, is to be preferred to ſpring water, but for works expoſed to the action of the ſea, ſuch as piers, light-houſes, &c. it is uſually more convenient, and equally advantageous in other reſpects to uſe ſalt water. The great point, and which is too often neglected, is not to put in too much of either one or the other: it is infinitely better to employ no more than is requiſite to ſlack the lime, and ſo incorporate the materials at the expence of a little more labour than by a ſuperfluity of water to bring the whole to the proper conſiſtence without beating.

§ 3. *Maltha or Maſtich.*

Under this term we include thoſe calcareous cements of a more complicated kind whoſe hardneſs appears to depend on the oily and mucilaginous ſubſtances that enter into their compoſition. The uſe of theſe is at preſent very limited, at leaſt in Europe, but they were highly eſteemed by the ancients, eſpecially for ſtucco.

[1] Journ. de Phys. i. p 370. [1] Smeaton.

The Maltha of the Greeks ſeems to have been more ſimple than that employed by the Roman architects; at leaſt we are informed that Panænus, the brother of Phidias, lined the inſide of the temple of Minerva, at Elis, with a ſtucco, in which the uſual materials (ſand and lime) were mixed up with milk inſtead of water, ſome ſaffron being alſo added to give it a yellow tinge. The Roman Maltha, according to Pliny,[k] was prepared in the following manner. Take freſh burnt lime, ſlack it with wine, and beat it up very well in a mortar with hog's-lard and figs: this cement if well made is exceſſively tenacious, and in a ſhort time becomes harder than ſtone: the ſurface to which it is to be applied is to be previouſly oiled in order to make it adhere. Another kind almoſt equally ſtrong and conſiderably cheaper was prepared by beating up together fine ſlacked lime, pulverized iron ſcales, and bullock's blood. In the preparation of maſtichs, as well as of every other kind of mortar, ſo much depends on the manipulation, and eſpecially on the care which is taken to incorporate the ingredients by *long* beating, that thoſe countries in which labour is of the leaſt value poſſeſs in general the beſt mortar. Hence no doubt principally ariſes the unrivalled excellence of the mortar made by the Tuniſians and other inhabitants of the northern coaſt of Africa, which, according to Dr. Shaw, is prepared in the following manner. One meaſure of ſand, two of wood aſhes, and three of lime, being previouſly ſifted, are mixed together, and ſprinkled with a little water; after the maſs has been beaten ſome time a little oil is added: the beating is carried on for three days ſucceſſively, and as the evaporation in that hot climate is conſiderable, the cement is kept at the proper degree of ſoftneſs by the alternate addition of very ſmall quantities of water and oil. The cement being compleated is applied in the uſual manner, and ſpeedily acquires a ſtony hardneſs. The laſt ſpecies of Maltha that we ſhall mention is the celebrated chunam of India, where it has been uſed from time immemorial. The method in which it is prepared at Madras is as follows.[l]

Take 15 buſhels of pit ſand, and 15 buſhels of ſtone lime, ſlack the latter with water, and when it has fallen to powder mix the two ingredients together, and let them remain untouched for three days. In the mean time diſſolve 20 lbs. of molaſſes in water, boil a peck of gramm (a kind of pea) to a gelly; boil a peck of mirabolans alſo to a gelly, mix the three liquors and incorporate part of the mixture very accurately with the lime and ſand, ſo as to make a very fluid cement: ſome ſhort tow is now to be well beaten into it, and it is then fit for uſe. The bricks are to be bedded in as thin a layer as poſſible of this mortar, and when the workmen leave off, though but for an hour, the part where they recommence working is to be well moiſtened with ſome of the above liquor before the application of any freſh mortar. When this is uſed for ſtucco, the white of four or five eggs, 4 oz. of butter, or ſeſamum oil, and a pint of butter-milk, are to be ground up with every half buſhel of cement, and the mixture is to be applied immediately.

It is to be regretted that no experiments have as yet been inſtituted to aſcertain the cauſe of the induration of calcareous cements: it is obviouſly not owing to the abſorption of carbonic acid, becauſe in numerous inſtances the cement hardens long before the lime is ſaturated: in the different kinds of maltha the lime combines with the albumen, mucilage, and oil, with which it is in contact, and in all probability takes up little or no carbonic acid, and if it is true that the lime in old mortar cannot, by burning, be reconverted into quicklime, it may reaſonably be queſtioned whether, even in the ſimple calcareous cements, carbonic acid acts ſo important a part as is uſually attributed to it.

CERUMEN, or *Ear Wax*.

This ſecretion is known to be a yellow glutinous ſubſtance, extremely bitter, which is always contained in greater or leſs quantity in the canal from the external ear to the tympanum. By the analyſis of Vauquelin[m] it appears to be conſiderably combuſtible, and largely ſoluble in alcohol; the reſidue not acted on by this liquor readily unites with alkalies. It appears to be compoſed of a fat oil reſembling that of the bile; of an albuminous mucilage; and of a peculiar colouring matter, in which alſo the bitterneſs ſeems to reſide. The quantity collected was too ſmall for a more accurate examination.

The uſe of the ear-wax is not preciſely known, but a due quantity of it ſeems eſſential to the ſenſe of hearing. It is readily ſoftened by ſtrong ſoap and water, which forms a good injection to looſen it from the ears when it has collected in too large quantity, a very common cauſe of deafneſs.

CERUSSE, or *White Lead*, is a white oxyd of this metal prepared by the vapour of vinegar. See LEAD.

[k] Hiſt. Nat. lib. ch. 53. [l] Phil. Tranſ. xxxvii. p. 231. [m] Fourcroy Syſt. des Connoiſſ. Chim.

CERUSSE OF ANTIMONY is a perfect oxyd of antimony prepared by nitre. See ANTIMONY.

CHALCEDONY.[a]

Of this mineral there are two ſubſpecies.

1. Subſpecies. Common Chalcedony. *Gemeiner Kalzedon*, Werner. *Calcedoine*, Fr. *Quartz agathe calcedoine*. Hauy.

The colour of chalcedony is bluiſh grey, paſſing into milk-white and ſmalt-blue; greeniſh grey, paſſing into apple and olive green; and yellowiſh grey, paſſing into wax and ochre-yellow, yellowiſh and blackiſh brown, and browniſh black. Two or more of theſe colours are not unfrequently found in the ſame ſpecimen, of which one generally forms the baſis, while the others are diſtributed over its ſurface in dots, clouds, or ſtripes: when white and yellowiſh brown ſtripes, alternate with each other, the ſtone is called an *onyx*, and is highly eſteemed by the lapidaries. The grey varieties, with thick priſmatic diſtinct concretions, when tranſverſely cut, preſent irideſcent colours when held to the light, and have hence been named *rainbow chalcedony*. The tranſlucid milk-white variety is called *cacholong*. The green and ſmalt-blue varieties are the rareſt; the dark coloured ones when cut thin and held to a ſtrong light, appear blood-red.

It is found maſſive, forming veins, in round balls of various ſizes, called geodes, alſo kidney-ſhaped, botryoidal, ſtalactitic, mamillated, and impreſſed by various organized bodies, ſuch as turbinites, &c.: certain cryſtalline forms, eſpecially thoſe of quartz have alſo been attributed to chalcedony, but theſe appear to be nothing more than cryſtals of quartz coated over with chalcedony. It poſſeſſes little or no luſtre. Its fracture is perfectly even, paſſing into fine ſplintery and flat conchoidal. It breaks into indeterminate ſharp-edged fragments. It frequently exhibits concentric lamellar or angular diſtinct concretions. It is commonly ſemitranſparent; but the darker coloured varieties are only tranſlucent. It is ſomewhat harder than flint, and by no means ſo eaſily broken. Sp. gr. 2.58 2.65. It is infuſible *per ſe* before the blowpipe, but becomes milk-white and opake. According to Bergman the chalcedony from Ferroe conſiſts of

84. Silex
16. Alumine, and a little iron

100

It occurs in geodes and veins in Amygdaloid; alſo in veins accompanied by quartz, pyrites, &c. in porphyry. It was anciently procured from Chalcedon in leſſer Aſia, whence its name, but at preſent is found principally in Scotland and the adjoining iſlands, in Cornwall, Iceland, Saxony, Hungary, Piedmont, and various parts of Aſiatic Ruſſia.

2d Subſpecies, Carnelian. *Karniol*, Werner. *Carnaline*, Fr.

The uſual colour of this mineral is blood-red, whence it paſſes into fleſh-red, reddiſh-white, milk-white, orange, and honey-yellow: two or more colours often occur in the ſame ſpecimen, diſpoſed in zones, ſtripes, and arborizations. It occurs in veins and rounded pieces; has a conchoidal fracture and a ſlight degree of luſtre. In other reſpects it agrees with common chalcedony. The variety with alternate white and red ſtripes, is called *Sardonyx*. Carnelian is found in various parts of Europe, but the moſt beautiful and valuable pieces are brought from Arabia, and Surat, and Cambay in India. Carnelian from its beauty and hardneſs, has always been much ſought after by lapidaries, ſome of the fineſt antique cameos are formed of it.

It is cuſtomary among modern mineralogiſts to place *agate* as an appendage to the ſpecies of chalcedony, ſince it is to this mineral that the former is indebted for its moſt ſtriking characters, and becauſe the coloured chalcedonies paſs imperceptibly into agate.

Agate is a mixture of chalcedony, carnelian, jaſper, hornſtone, quartz, heliotrope, amethyſt, and indurated lithomarga, aggregated into binary or more complex combinations. It has nevertheleſs ſeveral characters by which it may be diſtinguiſhed from other minerals.

Although it conſiſts of parts differing from each other in colour and tranſparency, yet theſe poſſeſs a certain uniformity of arrangement, and ſlide into each other by ſuch nice gradations, as ſhow them to have been all of ſimultaneous formation. As it differs in the colour of its conſtituent parts, ſo it does alſo in their tranſparency; it is never wholly opake like jaſper, nor tranſparent like quartz cryſtal: it takes a very high poliſh, and its opaker parts uſually preſent the appearance of dots, eyes, veins, zones, clouds, bands, or ramifications.

It is found in the form of irregular rounded nodules, from the ſize of a pin's-head to more than a foot in diameter, or in veins or ſtrata, and ſometimes ſtalactitic. Several varieties of agate are diſtinguiſhed by lapidaries. The finer

[a] Emmerling, Brochant, Kirwan, Hauy.

kinds conſiſting chiefly of chalcedony, carnelian, and heliotrope, are called oriental. In the banded or ribbon-agate, the colours are diſpoſed in ſtrait parallel lines or bands. In the fortification agate, the moſt beautiful of all the varieties, the colours are arranged in waved and angular parallel zones. The landſcape or ruin agate repreſents rocks or buildings. The tube-agate is a congeries of hollow ſtalactites of chalcedony filled with, and imbedded in carnelian, jaſper, &c. The moſs agate, called *Mocha ſtone*, from a corruption of the German mochs-ſtein (moſs-ſtone) conſiſts of chalcedony or carnelian, penetrated by arboreſcent iron ore, which, when the filaments are delicate, has a very beautiful appearance.

Agates are found for the moſt part in nodules in Amygdaloid, and ſometimes in Gypſum: near the river Wolga they occur between ſtrata of ſecondary lime-ſtone; and in Siberia certain rocky tracts conſiſt of banks of pudding-ſtone, of which agate and chalcedony form the principal part.

The moſt beautiful agates that this iſland produces are called Scotch pebbles, and are found principally in the neighbourhood of Perth and Dunbar. The moſt celebrated however in Europe, are thoſe of Oberſtein in the Duchy of Deuxponts. Thoſe of Siberia are eminently beautiful, but the moſt eſteemed of all come from Ceylon and other parts of India.

Agate is cut into cameos or ſeal-ſtones, is hollowed into ſnuff-boxes, or ſawn into thin plates for inlaying tables, and is applied to other ornamental purpoſes. The commoner kinds are made into mortars for the enameller and chemiſt, as from their hardneſs they are not liable to be materially abraded by pulverizing the hardeſt glaſs and ſtones in them. The coarſeſt fragments that are applicable to no other uſe are formed into the white gunflints, which are harder than common flint, and not ſo brittle.

CHALK. *Kreide*, Werner. *Craie*, Fr.

The colour of this mineral is yellowiſh white, more rarely ſnow-white or greyiſh white; when contaminated with iron it has more or leſs of an ochery tinge. It occurs generally in maſs, ſometimes diſſeminated, or inveſting other minerals. It is without luſtre, is opake, has a fine earthy fracture, and breaks into blunt edged angular fragments. It ſtains the fingers, gives a white ſtreak, and when pure is very ſoft and almoſt friable It has a meagre feel and adheres to the tongue. Sp. gr. about 2.3. It effervesces violently with acids. When mixed with iron it becomes both harder and heavier.

In a ſtate of purity chalk appears to be compoſed only of lime, carbonic acid, and water, but a ſpecimen analyzed by Mr. Kirwan afforded him

53.	lime
42.	carbonic acid
3.	water
2.	alumine
100	

Chalk, where it is found at all, is the preponderating ſubſtance, and may therefore be conſidered as characterizing a peculiar ſpecies of mineral formation. It is perhaps the moſt recent of all the varieties of calcareous carbonat, it occurs in ſtrata for the moſt part nearly horizontal, alternating with thin layers of flint nodules, and with the ſame irregularly diſperſed through its ſubſtance: it contains in abundance the relics of marine organized bodies, ſuch as echinites, gloſſopetræ, pectinites, &c. and alſo not unfrequently the hard parts of amphibious and land animals, as the heads and vertebræ of crocodiles, and teeth of elephants. Chalk hills never riſe to a higher elevation than three or four hundred feet, and are at once diſtinguiſhable by the ſmooth regularity of their outline, and their remarkable tendency to form cup-ſhaped concavities. Ridges of chalk, in England at leaſt, are always bordered by parallel ranges of ſand or ſandſtone, beneath and alternating with which are ſituated the beds of fullers earth. Chalk-hills are alſo ſingularly characterized by their dryneſs and their verdure: the moſt porous ſandſtone is ſcarcely ſo deficient in ſprings of water, and yet except upon almoſt perpendicular deſcents, the white ſurface of the chalk is uniformly covered with fine turf or wood.

The chalk-hills in England occupy a greater extent than in any other country, they run in a direction nearly from eaſt to weſt parallel to each other, and ſeparated by ranges of ſandſtone, and low tracts of gravel and clay. The moſt northern and loftieſt range of chalk commences at the promontory of Flamborough-head, in Yorkſhire, and proceeds weſtward for nearly 20 miles. In the county of Lincoln are ſome fragments of a ridge near Grantham. Two ridges traverſe the midland counties, and reach as far weſt as the borders of Oxfordſhire: theſe ridges are no where ſo conſpicuous as in the county of Bedford, where they approach near to each other, being only ſeparated by the Woburn and Ampthill range of ſandſtone. The country ſouth of the Thames alſo contains two ridges,

the one commencing at the North and South Forelands, paſſing through the north of Kent, the middle of Surry, and the north of Hampſhire, and including the North Downs of Banſtead, Epſom, &c.; the other commencing near Haſtings and at the lofty promontory of Beachy-head, paſſes through Suſſex and the ſouth of Hampſhire, into Dorſetſhire, including the South Downs.

The north part of France alſo abounds in chalk: it is beſides met with in ſome of the Daniſh iſlands in the Baltic, and in Poland.

The uſes of chalk are very extenſive: the more compact kinds are uſed as building ſtone, and are burnt to lime (nearly all the buildings in London being cemented with chalk-mortar): it is alſo largely employed in the poliſhing of metals and glaſs, in conſtructing moulds to caſt metal in, by carpenters and others as a material to mark with, and by ſtarch-makers and chemiſts to dry precipitates on, for which it is peculiarly qualified on account of the remarkable facility with which it abſorbs water.

CHALK, *Spaniſh.* } See STEATITE.
CHALK, *French.* }

CHARCOAL. See CARBON.

CHEESE. See MILK.

CHERT. See HORNSTONE.

CHLORITE.[a]

There are four ſub-ſpecies of this mineral.

1. Earthy Chlorite, *Chloriterde*, Werner.

Its colour is intermediate between dark mountain green and blackiſh green: it is compoſed of minute ſomewhat ſhining ſcales, either looſe or ſlightly coherent: it does not ſtain the fingers, but gives a ſhining green ſtreak: it feels rather greaſy, is light, and when breathed on, gives a ſtrong argillaceous odour.

Earthy chlorite melts before the blow-pipe to a dark-coloured ſhining ſlag, which is attracted by the magnet. According to an analyſis by Vauquelin, it conſiſts of

8.	Magneſia
26.	Silex
18.5	Alumine
43.	Oxyd of iron
2.	Muriat of ſoda
2.	Water
99.5	

It occurs for the moſt part in primitive mountains of argillaceous ſchiſtus mixed with quartz, common chlorite, calcareous ſpar, and micaceous iron ore. It is alſo contained in granular lime-ſtone and primitive ſand-ſtone. By expoſure to the air it decompoſes into a yellow ochery maſs.

It is found in Saxony, Switzerland, Norway, Sweden, Hungary, and North Wales.

2. Common Chlorite, *Gemeiner Chlorit*, Werner.

The colour of this mineral reſembles that of the preceding, except that it is a little darker. It occurs in maſs and diſſeminated, has a gliſtening luſtre, and a fine foliated fracture paſſing into earthy. It is ſoft, gives a light-green ſtreak, and has a greaſy feel. Sp. gr. 2.83.

It conſiſts, according to Höpfner, of

39	Magneſia
41	Silex
6	Alumine
1	Lime
10	Oxyd of iron
97	

By the action of the blow-pipe it acquires a browniſh-yellow colour.

It is generally found in metalliferous veins, but is alſo found in veins of quartz.

3. Chlorite-ſlate, *Chloritſchiefer*, Werner.

Its colour is a dull green of various degrees of intenſity from greeniſh-grey to greeniſh-black: it occurs only in maſs; it has a gliſtening and greaſy or reſinous luſtre. Its fracture is curved or waved foliated: thoſe varieties that have the greateſt degree of luſtre are uſually ſcaly foliated, When broken it flies into blunt-edged ſlaty fragments. It is opake, is ſoft, has a greaſy feel, and gives a mountain-green ſtreak. Sp. gr. 2.98.

It does not melt *per ſe* before the blow-pipe, but by a continued heat becomes white.

Chlorite ſlate is one of the primitive rocks, and is generally found in layers alternating with argillaceous ſchiſtus, ſometimes, though rarely with gneiſs. It paſſes into micaceous ſchiſtus and hornblende ſlate, and often contains imbedded cryſtals of garnet or octohedral magnetic iron ore.

4. Foliated Chlorite, *Blättriger chlorit*, Werner.

The colour of this mineral is dark-green. It occurs in maſs or diſſeminated, or cryſtallized in hexagonal tables, or ſix-ſided priſms terminated by pyramids, the angles of which are rounded off ſo as to reſemble a cylinder terminated by a cone. The ſurface of the cryſtals is ſtreaked and gliſtening; its internal luſtre is ſhining and pearly; its fracture is foliated, generally curved, and the laminæ are in ſome

[a] Emmerling. Hauy. Jameſon.

degree flexible. It is tranſlucent on the edges, is ſoft and eaſy frangible. It contains according to Lampadius,

35.	Silex
29.9	Magneſia
18.	Alumine
9.7	Oxyd of iron
2.7	Water
95.3	

It occurs in the Duchy of Salzburg, and Mont St. Gothard, in Switzerland, accompanied by priſmatic cryſtals of titanium; it has alſo been found in the Iſland of Jura in the Hebrides. It ſeems to be conſidered by Hauy as a variety of Mica.

CHROME.

Chrome is a metallic ſubſtance of a greyiſh white colour, extremely brittle, acidifiable with difficulty by nitric acid, and then capable of combining into a lemon-yellow ſalt with cauſtic potaſh. This ſalt being added in ſolution to nitrat of lead occaſions a deep orange-red precipitate of chromated lead.

Chrome has hitherto been only found in the acid ſtate combined with lead and with iron.[a]

Sp. 1. Chromat of Lead; *Red Lead-ſpar*, Kirw. *Rothes Bleyerz*, Werner. *Plomb rouge*, Broch. *Plomb Chromaté*, Hauy.

The colour of this mineral is aurora-red paſſing into hyacinth-red: it occurs very rarely in maſs, ſometimes diſſeminated, but moſt commonly cryſtallized. Its primitive cryſtalline form is that of a rectangular priſm diviſible along the diagonals of its baſe into trihedral priſms: it is alſo found with two of the lateral edges of the priſms truncated, thus forming a ſix-ſided priſm, two of the faces of which are much wider than the reſt; ſometimes all the lateral edges are truncated, whence reſults an eight-ſided priſm. The cryſtals are of moderate ſize, adhering laterally to each other, and generally very imperfect and ill-defined: the lateral faces are ſlightly ſtriated longitudinally, and have a brilliant external luſtre. The fracture is fine-grained uneven, paſſing into conchoidal, and irregularly lamellar. It breaks into blunt-edged indeterminate fragments. It is tranſlucid, paſſing into ſemitranſparent, is brittle, eaſily frangible, and, when ſcraped, gives a yellowiſh orange coloured powder. Sp. gr. 6.02.

Chromat of lead when expoſed to the blow-pipe crackles a little, and melts into a blackiſh ſlag: with borax it is in part reduced to the metallic ſtate, and communicates a green colour to the flux. The reſults of its analyſis by Vauquelin were

63.96	Oxyd of lead
36.40	Chromic acid
100.36	

The only ſubſtances liable to be confounded with this mineral are realgar and red-ſilver; the firſt of theſe however differs from the chromat of lead in its inferior ſpecific gravity, its volatility before the blow-pipe, and its arſenical odour when heated; the ſecond is diſtinguiſhed by its colour which is a pure red without any mixture of orange, and by its ſuperior metallic luſtre.

Chromat of lead has hitherto been found only in the gold mine of Berezof, to the north of Ekaterinenburg, on the eaſtern ſide of the Uralian mountains: it is thinly diſperſed in a vein paſſing through gneiſs and micaceous ſchiſtus, accompanied by quartz, galena, and auriferous pyrites. None of the cryſtallized varieties have been found for ſome years, in conſequence of which they are now ſold at a moſt enormous price, being valued at their weight in gold. The only uſe to which this ſubſtance has been applied is as a pigment: it is in high eſteem among the Ruſſian painters both on account of the unalterability and beauty of its colour.

Sp. 2. Chromat of iron. *Fer Chromaté*, Hauy and Broch.

The colour of this mineral is greyiſh or blackiſh-brown; it occurs in maſs; it poſſeſſes a ſlight degree of metallic luſtre; its fracture is compact, uneven, ſometimes imperfectly lamellar; when pulverized it is of an aſh-coloured grey. It is ſufficiently hard to ſcratch glaſs, is difficult to break, is opake, and gives an argillaceous odour when breathed on. Sp. gr. 4.03.

It is infuſible before the blow-pipe without addition, but with borax it melts into a beautiful green-coloured glaſs. It contains according to the analyſis of Vauquelin,

43	Chromic acid
35	Oxyd of iron
20	Alumine
2	Silex
100	

Chromat of iron is ſaid to have been found in Siberia; it has alſo been diſcovered in France near Gaſſin, in the department of Var, forming

[a] Hauy. Brochant.

nodules and veins in ſerpentine; ſome of the nodules are nearly a cubic yard in magnitude.

The method of analyſing the chromat of lead is very ſimple. Vauquelin has pointed out two ways,[b] both of which we ſhall mention, only obſerving that the laſt is upon the whole the moſt ſatisfactory.

Take one part of finely pulverized chromat of lead, three parts of perfectly ſaturated carbonat of potaſh, and forty parts of water, and boil the mixture together for the ſpace of an hour. As ſoon as the ſubſtances begin to act on each other, a briſk effervescence will take place, the orange colour of the lead will begin to change to brick-red, and finally when the effervescence has ceaſed, there will remain at the bottom of the veſſel a powder of a dirty yellow colour conſiſting of carbonat and chromat of lead, covered by a clear liquor of a bright golden yellow, which is chromat of potaſh. The liquor being poured off, and the powder well waſhed, ſome very dilute nitric acid is to be poured on the powder till it ceaſes to effervesce; the colourleſs ſolution thus obtained is nitrat of lead, while the undecompoſed reſidue of chromated lead will remain unaltered, and is afterwards to be decompoſed by a ſecond digeſtion with thrice its weight of carbonated potaſh. The nitric ſolutions of lead being mixed together are to be decompoſed by ſulphat of ſoda, and the lead contained in the ore is to be eſtimated from the ſulphat of lead thus procured. The alkaline ſolutions of chromic acid being mixed with the waſhings, are to be mixed with weak nitric acid as long as any carbonic acid from the undecompoſed carbonat of potaſh, is given out, and the liquor by ſubſequent evaporation and cooling depoſits cryſtals of chromat of potaſh mixed with nitre.

The ſecond method of decompoſing this ſubſtance is, to digeſt together, at a moderate temperature, equal weights of chromat of lead very finely pulverized, ſtrong and pure muriatic acid, and diſtilled water, taking care to ſtir the mixture from time to time. The chromat of lead will be decompoſed, and will change to a white colour, being converted for the moſt part to muriat of lead. When the acid has ceaſed to act, the liquor muſt be poured off, and freſh muriatic acid (diluted as before with water) to the amount of about one-fourth of the former quantity is to be digeſted with the reſidue till no more orange-coloured grains appear among the white muriat. The liquor being added to the former, together with the waſhings, the whole after being heated is to be placed for a few days in a cool place, that the ſmall quantity of muriated lead, which it holds, may be depoſited; when this is removed ſome oxyd of ſilver, precipitated from its ſolution in nitric acid by cauſtic potaſh, is to be added very gradually till the laſt portions acquire a red purple colour, thus the whole of the muriatic acid will be got rid of, and the liquors will contain only chromic acid, which, by ſlow evaporation, is depoſited in ſmall priſmatic ruby-red cryſtals.

The decompoſition of chromat of iron is not effected by any means ſo eaſily as of chromated lead. The action of muriatic or oxymuriatic acid upon it is very ſlow and imperfect, nor is a boiling ſolution of either pure or carbonated potaſh attended with any better ſucceſs. The moſt effectual way of proceeding according to Taffaert and Vauquelin[c] is to fuſe in a platina crucible the finely pounded ore with an equal weight of cauſtic potaſh, then to ſeparate all that is ſoluble in water, and treat the reſidue with hot muriatic acid. By the alternate uſe of theſe menſtrua for ſix or ſeven times each, the whole of the ore will be taken up and diſſolved. The muriatic ſolution being evaporated nearly to dryneſs, and then left to cool, will become gelatinous, thus announcing the preſence of ſilex which may be obtained by rediſſolving the gelly in water, in conſequence of which the ſilex will be precipitated; the clear liquor being then treated with ammonia the iron will be obtained in the ſtate of oxyd. The muriatic ſolution being thus exhauſted, the alkaline ſolution is to be carefully neutralized by nitric acid, by which means the alumine will be precipitated, and nothing will be left in the liquor but chromat of potaſh and nitre, from which the chromic acid may be obtained pure by adding nitrat of lead till no further precipitate takes place, and then treating the chromat of lead thus formed with muriatic acid, as mentioned above.

Chromic acid is of an orange red colour, and a pungent metallic taſte; it is very ſoluble in water, and, by gentle evaporation, cryſtallizes in lengthened priſms. Like other acids it combines with the ſalifiable baſes, whence reſults a genus of compound ſalts called *chromats*, the chief of which we ſhall proceed to deſcribe.

Chromat of Barytes is formed by mixing together the aqueous ſolutions of barytes and chromic acid: it appears as a pale lemon-yellow precipitate, is ſparingly ſoluble in water, and has no perceptible taſte. When heated, it gives out oxygen gas, and aſſumes a green colour.

[b] Journal des Mines, No. 34, p. 744. [c] Ibid. No. 55, p. 522.

Chromat of Lime is prepared like the preceding: by adding the liquid acid to lime-water, an orange-yellow precipitate falls down, differing from the chromat of barytes only in being leſs ſoluble, and in a ſomewhat different order of affinities.

The carbonated *alkalies* are decompoſed with effervescence by chromic acid, forming very ſoluble and cryſtallizable ſalts of a lemon-yellow colour. The chromat of ammonia is deſtroyed by a red-heat, the alkaline baſe being decompoſed, and deoxygenating the acid ſo that only a green oxyd of chrome remains behind. The alkaline chromats are decompoſable with abſtraction of their acid by barytes, lime, and ſtrontian, and with abſtraction of their baſe by the mineral acids: when added to any of the ſoluble metallic ſalts a double decompoſition takes place, and the chromated metal is precipitated in form of a coloured powder; mercury gives a vermillion-red precipitate, ſilver a carmine-red, lead an orange-yellow, tin a green, &c.

Chromic acid appears to be very eaſily reducible to the ſtate of oxyd, in which ſtate it is generally of a green colour. Thus, when heated on charcoal before the blow-pipe, it firſt boils, and when the moiſture is evaporated, a green pulverulent infuſible oxyd remains. By fuſion with borax and glaſs of phoſphorus it affords vitreous globules of a bright emerald green. With tannin chromic acid forms an inſoluble yellowiſh-brown flocculent ſediment, and with hydroſulphuret of potaſh a browniſh-green one.

Muriatic and chromic acids when heated together in a retort occaſion a conſiderable effervescence; part of the muriatic acid is converted into oxymuriatic acid which flies off, and the chromic acid is changed into the green oxyd. Ether or alcohol when heated for a few ſeconds with this acid produce a ſimilar effect; as does alſo muriat of tin, the ſame metal in the reguline ſtate, iron, zinc, and moſt of the other metallic ſubſtances. Even light will decompoſe chromic acid, for a paper wetted by it, and expoſed during a few days to the ſun, aſſumes a permanent green colour.

In order to reduce chromic acid to a regulus, it is ſufficient to heat it ſtrongly in a crucible lined with charcoal, the reſult will be a brittle, brilliant, greyiſh white metallic button amounting to about 67 *per cent.* of the acid employed. At a high temperature it aſſumes the form of feathery cryſtals. A fragment of this metal when expoſed to the blow-pipe, firſt tarniſhes, and then acquires a thin coating of greeniſh oxyd. When finely pulverized, and treated with concentrated boiling nitric acid, it is oxydated with extreme difficulty, and gives the acid a light bluiſh-green colour; by repeated abſtractions it is at length compleatly acidifiſed, and then exhibits exactly the ſame characters as the native acid.

Chrome on account of its ſcarcity, and the ſhort time that it has been known has not yet been applied to any uſe; it is probably however capable of furniſhing ſome fine pigments to the painter and enameller: in particular it will tinge glaſs with a true EMERALD green; the colouring matter of this beautiful gem having been recently proved to be this very metallic oxyd.

CHRYSOBERYL[a]. *Cymophane* of Hauy. *Oriental* and *opaleſcent Chryſolite* of ſome naturaliſts.

The colour of this mineral is aſparagus-green, paſſing into greeniſh-white on one ſide, and on the other through olive green into yellowiſh-grey, and ſometimes reddiſh-brown. It generally exhibits a bluiſh milky light, undulating within the cryſtals. It is uſually met with in ſmall rounded pieces, but occaſionally poſſeſſes a well marked cryſtalline figure. Its primitive form is that of a rectangular parallelopiped, and the figures which it has hitherto been obſerved to affect are,

1. A ſhort, regular hexahedral priſm or table.
2. The ſame with a truncated hexahedral pyramid raiſed upon each baſe.

The ſurface of the rounded pieces is ſomewhat rough, and generally reflects glittering variegated colours. The cryſtals poſſeſs a double refraction, are externally ſhining, and very brilliant internally, ſo that when poliſhed it may often be confounded with the yellow diamond. The fracture of chryſoberyl is perfectly conchoidal; its fragments are indeterminately angular, and ſharp-edged; its hardneſs is ſuperior to that of quartz; its ſp. gr. is = 3.7.

It is infuſible *per ſe* before the blow-pipe; and conſiſts, according to the analyſis of Klaproth[b], of

Alumine .	71.5
Lime . .	6.
Oxyd of iron	1.5
Silex . . .	18.
	97.0
Loſs	3.
	100.

It is procured chiefly from Brazil, where it

[a] Emmerling. Brochant. Hauy. Jameſon. [b] Analyt. Eſſ. 1. p. 85.

accompanies the topazes: it has alſo been diſcovered by Count Bournon in ſand from the iſland of Ceylon, together with rubies and ſapphires. A few ſpecimens have been brought from Nertschinſk in Siberia. It is however upon the whole a very rare mineral, and from its hardneſs and luſtre is conſiderably valued by jewellers.

CHRYSOLITE. *Peridot* of Hauy.

The principal colour of this mineral is piſtachia-green, paſſing into browniſh-olive. It occurs in angular or rounded fragments, or cryſtallized. Its primitive form is a ſtrait priſm with rectangular baſes, the other varieties of cryſtallization under which it appears are

1. An octagonal priſm terminated at each extremity by ſix faces oblique and one horizontal.

2. The ſame terminated by eight oblique faces correſponding to the ſides of the priſm, and one horizontal.

3. A ten-ſided priſm terminated by ſix oblique faces and one horizontal.

4. A twelve-ſided priſm terminated by eight oblique faces and one horizontal.

In all the varieties except the third thoſe faces in the priſm which are the remains of the long ſides of the original priſm are deeply ſtriated, while thoſe which are the remains of the ſhort ſides are remarkably ſmooth. The internal luſtre of the cryſtals is brilliant and vitreous. Its fracture is perfectly conchoidal; the fragments are indeterminately ſharp-edged. It is perfectly tranſparent, and poſſeſſes a double refraction in a very remarkable degree. Its hardneſs exceeds that of glaſs. Sp. gr. = 3.34.

It is infuſible *per ſe* before the blow-pipe, but with borax forms a tranſparent green glaſs.

It has been analyzed by Klaproth[a] and Vauquelin[b] with the following reſults.

	Klapr.	Vauq.
Silex	39.	38.
Magneſia	43.5	50.5
Oxyd of iron	19.	9.5
	101.5	98.0

It is not known with any certainty whence the chryſolite is procured: Upper Egypt is ſaid to be one of the countries which afford it, and a few come to the jewellers of Europe from the Eaſt Indies. It ranks among the gems, but its ſoftneſs and unattractive tone of colour, eſpecially when the yellow predominates, make it of little value.

CHRYSOLITE BRASILIAN, } See
———— ORIENTAL, } Chryso-
———— OPALESCENT, } beryl.

CHRYSOLITE VOLCANIC. See Olivin.

CHRYSOLITE VESUVIAN. See Vesuvian.

CHRYSOPAL. See Chrysoberyl.

CHRYSOPRASE. *Quartz-agathe praſe.* Hauy.

The colour of this mineral is apple-green, paſſing into graſs and olive-green and greeniſh-grey. It is found in maſs, in angular fragments and thick plates. Internally it exhibits a ſlight degree of luſtre. Its fracture is even, paſſing ſometimes into fine ſplintery and flat conchoidal, with indeterminate ſharp-edged fragments. Its hardneſs is ſomewhat leſs than that of Chalcedony. Sp. gr. 3.25.

Before the blow-pipe chryſopraſe becomes opake and colourleſs, but is infuſible *per ſe*. It has been analyſed with great accuracy by Klaproth[c], and appears to conſiſt of

Silex	96.16
Lime	0.83
Oxyd of Nickel	1.0
	97.99

It has hitherto been found only at Koſemutz in Lower Sileſia, imbedded in ſerpentine, along with quartz, opal, chalcedony, &c. It paſſes into hornſtone and chalcedony, and appears to differ from this laſt in little elſe than colour.

When kept long in a warm and dry ſituation it loſes the greateſt part of its colour. The apple-green variety is in ſome eſtimation among jewellers, and is cut into ſtones for rings.

CHYLE. The food of animals after it has undergone digeſtion in the ſtomach paſſes into the ſmall inteſtines, in which the alimentary part is ſeparated, and from which it is abſorbed or ſucked by ſmall veſſels called the *lacteals*, that convey it through a circuitous courſe finally into two veins, where it mixes with, and becomes blood.

Chyle therefore is the laſt change that food undergoes previous to its converſion into blood, and its analyſis would be ſcarcely leſs intereſting than that of blood itſelf, could it be collected conveniently, and in ſufficient quantity. Hitherto only a few deſultory experiments have been made, which are collected by Haller.[d]

By theſe we learn that chyle is a milky white fluid, of an agreeable ſub-ſaline taſte, lighter than the ſerum of blood, or even than water,

[a] Analyt. Eſſ. i. p. 91. [b] Journ. des Mines, No. 24. [c] Analyt. Eſſ. i. p. 420. [d] Elem. Phyſiolog. vol. 7.

on the ſurface of which it ſwims like cream, readily coagulating like blood by ſimple reſt and extravaſation, and appears to be compoſed of water, of an oily ſubſtance conſiſting of globules, of a heavier matter like cheeſe which remains at the bottom after coagulation, and of ſome earth. Chyle readily turns ſour by keeping, but gives no ſign of acidity when freſh. The nature of the aliment makes ſome, though a very ſmall change in the ſenſible qualities of chyle. Thus it is ſometimes tinged when colouring matter has been taken into the ſtomach.

It does not however ſhew any marks of containing iron, even when the animal has been in the habit of taking this metal.

CIMOLITE [a] of Klaproth. *Cimolia* of Pliny.

The colour of this mineral is a light greyiſh-white, inclining to pearl-grey; but by expoſure to the air it acquires a reddiſh tint. It occurs in maſs, forming large ſtrata; its fracture is earthy, uneven, and its texture more or leſs ſlaty. It is opake, of a greaſy luſtre, and may be ſcraped with a knife like ſteatite. It adheres firmly to the tongue, ſtains the fingers in ſome degree, and, though ſoft, is very tough, and difficultly pulverizable. Sp. gr.=2.0.

When expoſed to the action of the blow-pipe *per ſe*, it becomes at firſt of a dark grey colour, but afterwards recovers its whiteneſs with little or no alteration: with microcoſmic ſalt it runs into a colourleſs globule, with borax it forms a light brown glaſs. Its component parts are

Silex - -	63
Alumine -	23
Oxyd of iron	1.25
Water - -	12
	99.25

It abounds in the iſland of Cimola (whence its name) now called Argentiera, and was highly valued by the Greeks and Romans for its detergent properties; at preſent its uſe is almoſt entirely confined to the inhabitants of the iſland. When triturated with a little water it forms a ſoft pap-like maſs, and being applied in this ſtate to ſilk or woollen cloth, and allowed to dry on, it abſorbs all the greaſe which they may contain, like fullers' earth, but more effectually, and is again diſcharged by a ſlight waſhing, leaving the cloth reſtored to its original luſtre.

CINNABAR. See MERCURY.

CINNABAR, Native. See MERCURY, Ores of.

CIRCON. See ZIRCON.

CITRIC ACID. *Acid of Lemons. Zitronenſaure*, G.

Lemon juice is known univerſally to be one of the ſoureſt, and at the ſame time the moſt agreeable of all the native vegetable liquors. It is prepared ſimply by ſqueezing the fruit, and ſtraining through linen or any other looſe filter. In Sicily, Italy, Majorca, and many other parts of the Mediterranean, lemon juice forms an important article of commerce. It is procured ſimply by peeling the fruit, ſlicing it, and putting it in a large preſs with a cloth or hair ſtrainer.[a] The juice, which comes out very turbid, is placed for a day in cellars and then ſtrained, and put in jars with narrow necks well cemented up, the top of the juice being generally covered with a little oil, the better to defend it from the action of the air. Many of the preſſes will ſqueeze ſix thouſand lemons at once.

Lemon juice is a natural mixture, about the ſpecific gravity of, 1.034, compoſed of much water, of inſipid vegetable mucilage, of extractive matter, of a ſlight portion of ſomething that gives an aſtringent taſte, of a little malic acid, and laſtly of that peculiar acid, which, from its being contained more copiouſly in this fruit than in any other, is called the *citric* acid. The proportions of theſe ingredients muſt of courſe vary according to the degree of ripeneſs,[b] the ſeaſon, and the like, but on an average according to Prouſt, 576 grains of the freſh juice loſe by evaporation 528 grains, which is the watery part; and of the remaining 48 grains about 30 grains are the pure citric acid, and the remainder is chiefly mucilage and extract. On account of theſe two latter ingredients, lemon-juice ſooner or later, according to the temperature, ſpoils by keeping, becomes mouldy, undergoes an imperfect fermentation, and at laſt totally loſes its acidity, acquiring a flat muſty taſte.

To prevent this deſtruction of the acid for which alone this juice is valuable, many methods of preſervation have been deviſed, all of which anſwer to a certain degree, but none of them perfectly, except that of ſeparating the acid in a cryſtallized form by means which will be preſently mentioned. It ſhould be obſerved that of the mucilage and the extractive matter, (the two materials which principally contribute to ſpoiling the juice) the former alone is ſeparable by the ordinary methods of clarification, but the extract adheres to the acid with the greateſt obſtinacy, and it is this which hinders it from

[a] Analyt. Eſſ. i. p. 248. [a] Murray, Apparatus Medic. vol. iii. [b] Jour. de Phyſ. tom. lii.

cryſtallizing when evaporated nearly to dryneſs.

Lemon-juice is clarified partly by being put for a day or two in a cold cellar, remaining perfectly at reſt. Much of the mucilage then ſubſides, and the clear juice poured off, bottled, and carefully corked, will then keep for a conſiderable time. It is better if briſkly boiled for a minute or two before it is put aſide to clarify, but this ſomewhat impairs the flavour, and gives one that is not agreeable. In the Mediterranean, oil is poured over it to prevent the action of the air, which has a temporary effect, but after a while the juice beneath becomes muddy, bitter, mouldy, and beſides gets a rank taſte from the oil. Concentration by freezing is ſometimes uſed with ſome ſucceſs. If the mucilage is firſt ſeparated as much as may be by ſtanding in a *cool* place, and the clear juice then expoſed to a cold of from 23° to 26° the watery part alone freezes, and the remaining unfrozen liquor, of courſe, contains the acid in a condenſed ſtate. By continuing to remove the ice, till it begins to grow ſour from the acid itſelf freezing, lemon juice may be concentrated to about one-eighth of its former bulk, and is then clear, intenſely ſour, and will keep in a cool climate for ſeveral years unaltered.[c] Still however the extract entirely remains and part of the mucilage, and therefore in tropical climates even this concentrated juice ſpoils in no great length of time,[d] beſides the capital defect in the utility of the proceſs, that the cold which it requires can never be obtained naturally in the countries where the fruit grows, and at the ſeaſon in which it is moſt likely to ſpoil.

Sometimes certain mixtures are added to lemon juice to preſerve it. Forſter found in Cook's Voyage to the South Pole that the juice mixed with a fifth part of brandy or rum, in well cloſed caſks, kept very well for thirty-two months. Brugnatelli[e] propoſes to clarify the juice by alcohol. Freſh lemon juice was mixed with ſome ſtrong alcohol and bottled. In a few days a ſlimy mucilage had ſeparated, and the liquor filtered through paper, contained the purified juice with alcohol, which laſt may be ſeparated by evaporation. But it is obvious that this only very partially clarifies the juice, for the clear liquor, evaporated ſlowly to dryneſs, gives no cryſtals, but only a ſour extract. Beſides, the expenſe forbids its being uſed in the great way. Some perſons add ſulphuric or ſome other mineral acid to the juice, partly to preſerve and partly to adulterate it. The juice is indeed kept a long time from moulding by this addition, but the adulteration is often a ſerious inconvenience and loſs. Evaporation is certainly the beſt method of preſerving the juice in hot climates in its natural ſtate, that can be practiſed in the large way. This juice cannot be purified like vinegar by diſtillation, for, being leſs volatile than water, it will not riſe in vapour with a heat leſs than will decompoſe it; but if the freſh juice ſimply ſtrained be expoſed to a very *gentle* heat, the greater part of the water flies off without carrying away any of the acid, and when the liquor has nearly a ſyrupy conſiſtence (before it acquires a burnt taſte), it is then intenſely ſour, and will keep in bottles for many years, with very little alteration, and even retaining much of its original flavour. This inſpiſſated juice or *Rob* of Lemons, as it is called, if intended for the table, may be immediately mixed with dry white ſugar, which is known to preſerve all vegetable matter from corruption, and it will then keep for almoſt any length of time unimpaired, and is excellent for ſea voyages and domeſtic uſe. In hot climates the heat of the ſun is made to aſſiſt conſiderably in the evaporation.

But the pure citric acid cannot be obtained by ſuch ſimple methods, but a double proceſs of chemical affinity is required, firſt, by adding an intermede to ſeparate it from the other parts of the juice, and next to obtain it free from this addition in its cryſtallized form. This very ingenious proceſs was diſcovered by Scheele[f], and ſince has been followed by all ſucceeding chemiſts, with only a ſlight variation in the proportions and minutiæ of the proceſs. The intermede which this admirable chemiſt uſed was lime added in the form of chalk, the ſame that he had before employed for a ſimilar purpoſe in preparing the concrete acid of *Tartar*.

The mode he recommends is in a few words the following: Saturate boiling lemon juice with chalk in powder added gradually, till no more effervеſcence ariſes. The compound thence ariſing is a grey inſoluble maſs, the citrat of lime, which readily ſettles, leaving the mucilage, extract, and other ingredients of the juice in the ſupernatant liquor, which is thrown away, and the calcareous precipitate well waſhed with *cold* water till it is colourleſs. Then add to the precipitate a quantity of dilute ſulphuric acid, diluted with ten times its bulk of water, and equal in weight to the chalk uſed, and boil for a few minutes. This by ſtronger affinity unites with the lime, forming a ſulphat of lime

[c] Georgi from the Acta Soc. Petropol. [d] Proust. [e] Annali di Chemia, vol. ii. Ph. Mag. vol. ii. [f] Eſſays.

equally insoluble with the citrat, whilst the citric acid, now set free, remains dissolved in the clear liquor, and by due evaporation may be procured pure, and in large crystals. The sulphuric acid should be a little in excess to engage all the lime, otherwise the acid will not crystallize.

Such is the process of this excellent chemist, but as the preparation of this acid has lately become an object of some importance in manufacture, it may be of advantage to compare the particulars of the process as given by different chemists.

In preparing citric acid in the great way, M. Dizé[g] mentions the following particulars. After the citrat of lime has been decomposed by the sulphuric acid, *cold* water assisted by stirring is sufficient to wash out all the citric acid adhering to the sulphat of lime. This is of use both as saving fuel and as less of the calcareous sulphat is dissolved. Much however is still contained in the clear liquor, which in fact is a mixture of citric acid with the excess of sulphuric acid which it is necessary to add, and sulphat of lime held in solution. This liquor may be evaporated at a heat of boiling water. It is of a clear light yellow. As the bulk of liquid diminishes, the sulphat of lime falls down, and it is of use to suspend the evaporation once or twice for some hours, that by cooling the whole of the sulphat may be deposited. Towards the end, the liquor becomes blackish owing to the sulphuric acid becoming concentrated, and acting partly perhaps on the acid itself, and partly as the author imagines, on a portion of extractive matter, which subsides along with the citrat of lime, and which he thinks it is necessary to destroy in this manner before the citric acid will crystallize. This acid is so very soluble that the evaporation must be pushed to a very thick syrupy consistence before the crystals will separate. They are at first black and dirty. By re-solution in cold water (of which a small quantity will suffice) by filtration, and a second evaporation, they become yellow and more regular. A third crystallization seems necessary to make them white and pure. As there is much waste in these operations, the foul portion which will not pass the filter should be evaporated and treated as before.

Scheele has well remarked (and all other chemists have found the same) that an excess of sulphuric acid is required. M. Dizé supposes the peculiar use of this excess to be to destroy the remaining extractive matter, the existence of which he endeavours to prove by the proportions of ingredients required, and their products. One hundred pounds of the lemon juice he found to require for saturation 6.25 lb. of chalk, and to produce as much as 20 lb. of citrat of lime. On the other hand he found the crystallized citric acid to require its own weight of chalk for saturation, and to produce a quantity of citrat of lime equal to three-fourths of the weight of the two ingredients, the loss being chiefly carbonic acid. Hence he concludes that 100 lb. of fresh juice contains 6.25 lb. of the pure acid (that is equal in weight to the chalk required), and that the citrat of lime thence resulting if pure, aught to be no more than 9.378 lb. (being three-fourths of the sums of the weight of the chalk, and the supposed quantity of pure acid). But as it is really 20 lb. even after washing, he supposes this enormous difference to be made up by extractive matter precipitated along with the citrat of lime, and adhering to it. However the results of the experiments of other chemists do not give this difference, though they agree tolerably in other particulars. M. Dizé does not specify the quantity of crystallized acid actually obtained from a given quantity of juice.

Westrumb[h] saturated 4 lb. of fresh lemon juice, simply strained, with 3 ounces of chalk, and obtained 5 oz. and 1 dram of citrat of lime, which, decomposed with 23 drams of strong sulphuric acid diluted with about ten times its bulk of water, gave by due evaporation 2½ ounces of crystallized acid a little foul, which lost one dram by a second crystallization.

Professor Proust has examined the same process.[i] The ingredients and products given by those three chemists, reduced to the same proportion, are as follows:

[g] Journ. de Phys. [h] Leonhardi in Macquers Worterbuch Art. Citronensaure. [i] Jour. de Phys.

Lemon Juice	Chalk	Citrat of Lime	Citric Acid in cryſtals	Citric Acid
100lb. requires	4.25lb. and produces	7.51lb. yields	4.38lb. and contains	4.74lb. *Prouſt.*
for	by	by	by	
—— ſaturation	4.65— precipitation	8.9 — evaporation	3.90— eſtimation	—— *Weſtrumb.*
——	6.25—	20.	——	6.25— *Dizé.*

Cryſt.
Citric A.
6.25 6.25— 9.375 D°

With regard to the proportions given by Prouſt, it is to be obſerved that only 7.51 of citrat of lime was actually precipitated, but by evaporation of the liquor he obtained about $\frac{1}{44}$ additional, or .54lb. The cryſtallized acid was obtained from a known quantity of the waſhed citrat of lime, 6 ounces of the latter giving $3\frac{1}{2}$ of the acid, hence 7.51lb. would yield 4.38lb. the .54lb. of the citrat procured by evaporation would therefore yield .315 of the cryſtallized acid, which, added to 4.38 gives 4.695 for the quantity of acid, excluſive of the ſmall portion left in the laſt liquor after all the cryſtals have been removed, which the author eſtimates at a little more than $\frac{1}{100}$ of the quantity obtained, or in the preſent inſtance about .044, making a total of 4.74 of ſolid acid in 100 of the freſh juice.

The quantity of ſulphuric acid required for the decompoſition of the citrat is variouſly eſtimated, and as an exceſs of it is requiſite, at leaſt as much of the concentrated acid as will be equal to the chalk employed may be uſed, diluting it with about ten times its bulk of water. In this preparation therefore as the ſtrength of the lemon juice is uncertain, and, as it would appear, the product of citrat of lime equally ſo, and troubleſome to eſtimate, the quantity of chalk uſed ſeems the only proper guide to determine that of the ſulphuric acid demanded, and the probable yield of citric acid. Therefore the chalk ſhould be weighed, and the quantity uſed ſhould be noted, which ſhould be a little more than to ſaturation to engage the whole of the citric acid. If a portion of the ſame chalk be previouſly and ſeparately mixed with ſome of the ſulphuric acid intended to be uſed, and the quantity required for ſaturation be obſerved, it will furniſh a ſtill better guide for the ſecond part of the proceſs than that of uſing equal weights of chalk and acid. The clear ſupernatant liquor contains, beſides the mucilage and extract, a portion of *malat* of *lime* in ſolution, lemon juice containing a ſmall quantity of the malic acid. This calcareous ſalt is precipitated by alcohol, if the liquor is concentrated by evaporation. A minute portion of gallic acid alſo appears in lemon juice by the teſt of iron, the mixture turning of a brown red after being ſaturated with an alkali.

To ſeparate the citric acid compleatly from the lime, by the ſulphuric in the ſecond ſtep of the proceſs, Prouſt recommends boiling the whole for about five or ten minutes. The difficulty of ſeparating all the ſulphat of lime and extract from the diſengaged citric acid, and of procuring clear regular cryſtals has already been mentioned. A little alcohol added towards the end of the firſt evaporation, and ſubſidence for ſome hours greatly aſſiſts this ſeparation, and in the perfection of the cryſtals.

Richter gives another proceſs for preparing the citric acid,[k] which may be mentioned, though it does not appear that it is much uſed. Saturate lemon juice with carbonat of potaſh, then add ſufficient acetited lead. A copious white precipitate appears, which is the citrat of lead. When no more falls down, waſh the precipitate, digeſt with dilute ſulphuric acid (as in the former proceſs) to diſengage the citric acid, evaporate the liquor to a thick conſiſtence, add a few drops of nitric acid, and cryſtallize.

The theory of this operation is the ſame as in the former inſtance, ſubſtituting lead for lime, and with this difference that the lemon juice muſt firſt be ſaturated with alkali that the acetite of lead may be decompoſed by *double* affinity by the citrat of potaſh, and to prevent an exceſs of acid by which the citrat of lead is rendered very ſoluble, though without ſuch an exceſs it is ſcarcely diſſolved in any ſenſible degree. Where this acid is uſed for the table the introduction of ſo dangerous a metal as lead, particularly in its acid combinations, is a ſerious objection, and for manufacture it appears more expenſive than in Scheele's method.

Lemon juice when imported in this ſtate is not unfrequently adulterated with ſome ſtrong and cheaper acid. The ſulphuric is moſt to be ſuſpected. It is detected in the following ways

[k] Gren. Handb. der Chim.

put ſome of the juice in a glaſs, and add a ſolution of acetite of lead. This will produce a copious white ſediment in any caſe; after which add ſome drops of ſtrong nitric acid. If the juice contained no ſulphuric acid the white precipitate will be rediſſolved, and the liquor become again clear, the citrat of lead and malat (of which a ſmall portion will alſo be formed) being readily ſoluble in nitric acid, but if the juice was mixed with ſulphuric acid the ſulphat of lead will remain at the bottom. If this is collected, waſhed, and dried, the quantity of ſulphuric acid may be eſtimated from the known proportions of this ſalt. See *Lead*.

Pure citric acid cryſtallizes according to Lowitz[1] in alum-ſhaped cryſtals, conſiſting of two 4-ſided pyramids joined baſe to baſe, or, ſometimes, according to Dizé, in rhomboidal priſms. Its taſte is intenſely ſour, and, when diluted, very grateful to the palate. It is very ſoluble in water, one ounce of diſtilled water at a moderate heat diſſolving $1\frac{1}{4}$ ounce of the cryſtallized acid, and producing 30 degrees of cold by the mixture. In a boiling heat water diſſolves twice its weight of the acid. The cryſtals are not deliqueſcent. Diſtilled *per ſe* the products are an empyreumatic acid phlegm, carburetted hydrogen gas, and carbonic acid. It ſeems to be compoſed of carbon and hydrogen with oxygen in unknown proportions.

If this acid is boiled with a ſmall portion of nitric acid, much nitrous gas is given out, and the liquor evaporated and cryſtallized yields ſome oxalic acid. A greater proportion of nitric acid converts the whole into acetous acid, as it appears, without paſſing through the intermediate ſtate of the oxalic. Thus Weſtrumb obtained half a dram of oxalic acid from one dram of citric acid with 200 grains of the nitric: with 300 grains only $\frac{1}{4}$ of a dram; and with 600 grains not an atom.

Vauquelin aſſerts that this acid may be obtained by paſſing oxymuriatic acid gas through gum arabic in water for a conſiderable time.[m]

The culinary uſes of lemon juice are well known. The concrete citric acid may be often ſubſtituted for the juice with advantage where the latter is not conveniently procurable, but it is to be obſerved that none of the peculiar flavour of the fruit ſo agreeable in the freſh lemon paſſes into the ſolid acid, which is merely ſour, and without any particular aſtringency.

The uſe to which this acid has lately been put in manufacture is as a *diſcharger* of colour in calico-printing: the white figured parts of coloured patterns prepared with iron colours being produced with great clearneſs and effect by this acid. It is not abſolutely neceſſary to cryſtallize the acid for this purpoſe but only to concentrate it. The mineral acids anſwer equally as diſchargers, but when ſufficiently ſtrong to do this effectually, they injure the texture of the cotton.

Citrats. Of the ſalts formed by this acid with alkaline, earthy, and metallic baſes, only a few deſerve particular mention.

Citrat of Potaſh. This has long been known merely as a mixture in medicine under the name Riverius's ſalt. About 12 to 16 parts of lemon juice will ſaturate one of common carbonat of potaſh. To prepare it more accurately according to Vauquelin,[n] 36 parts of the cryſtallized acid diſſolved in water, require for ſaturation 61 parts of cryſtallized carbonat of potaſh. This ſalt cryſtallizes, though with difficulty, and is very deliqueſcent: 100 parts contain about 55.5 of acid, and 44.5 of alkali. It is decompoſed by barytes and lime.

Citrat of Soda. This is a very ſoluble cryſtallizable ſalt. According to Vauquelin, 36 parts of acid require 42 of dry carbonat of ſoda, ſo that 100 parts of the citrat of ſoda conſiſts of 60.7 of citric acid, and 39.3 of ſoda.

Citrat of Ammonia. Thirty-ſix parts of citric acid ſaturate 44 of carbonat of ammonia. Hence 100 parts of the ſalt contain 62 of acid, and 38 of ammonia. It is with difficulty cryſtallized, and is very ſoluble.

Citrat of Barytes. A hundred parts of this ſalt conſiſts of equal weights of citric acid and barytes. When barytic water is poured into citric acid, diſſolved in water, a precipitate is formed, which immediately is rediſſolved. But when approaching the point of ſaturation the barytic citrat is depoſited in quantity, at firſt pulverulent, afterwards in fine cluſtered cryſtalline needles.

Citrat of Magneſia. Thirty-ſix parts of the acid require for ſaturation 40 parts of carbonat of magneſia, and 100 parts of the ſalt contain 33.34 of magneſia, and 66.66 of acid. This is not cryſtallizable, but when nearly evaporated to dryneſs, the ſalt riſes in muſhroom-like knobs, white and opaque.

Citrat of Lime. This is the beſt known of the earthy citrats, being formed, as already mentioned, in the preparation of the citric acid. It is but ſparingly ſoluble in pure water, and the ſolution has very little taſte. But an exceſs of acid renders it extremely ſoluble, 100

[1] Gren's Handb.

[m] Ann. Chim. tom 6.

parts of citric acid, mixed with ſufficient water boiling hot, diſſolving 50 parts of the citrat of lime.[b] According to Vauquelin, 24 parts of the acid are ſaturated by 18 of calcareous ſpar. Hence 100 parts of the citrat of lime contain 37.34 of lime, and 62.66 of acid. Prouſt found that 100 parts of the citrat waſhed and dried, left by calcination 31.5 of lime, and hence the remaining 68.5 muſt be citric acid with water in undetermined proportions. Dizé found that the acid required an equal weight of pure chalk for ſaturation, hence (ſuppoſing the chalk to contain 53 per cent. of lime) 100 parts of the dry citrat perfectly free from extraneous matter, will conſiſt of about 65.4 of acid, and 34.6 of earth. This ſalt kept under water in a warm place ſoon grows mouldy, the acid is decompoſed, and the water is covered with a cruſt of carbonat of lime. Citrat of lime is decompoſed by the oxalic acid, or the oxalat of potaſh.

Metallic Citrats. Theſe have been but little examined. The acid diſſolves zinc and iron readily, and moſt of the oxyds of the other metals. It decompoſes acetite of lead, as already mentioned, and the citrat of lead is inſoluble in water without an exceſs of acid. Citrat of mercury is formed by adding this acid to the nitrat or acetite of mercury. The ſalt is a flakey precipitate of a brick-duſt red.

The affinities of the citric acid appear to be in the following order.

Barytes, lime, potaſh, ſoda, ſtrontian, magneſia, ammonia, and alumine. The comparative affinities of the metallic oxyds have not yet been determined.

CLARIFICATION is the ſeparation by chemical means of any liquid from ſubſtances ſuſpended in it, and rendering it turbid. If a difference can be made between clarification and *filtration*, it is that the latter is effected by mere mechanical means, but the former either by heat or by certain additions, the action of which may be conſidered as chiefly chemical. A few practical obſervations belong to both theſe articles.

The liquors ſubjected to clarification are almoſt without exception thoſe animal or vegetable juices, in which the matter that renders them turbid is ſo nearly of the ſame ſpecific gravity with the liquor itſelf that mere reſt will not effect a ſeparation. In theſe too the liquid is generally rendered thicker than uſual by holding in ſolution much mucilage, which further entangles the turbid matter, and prevents it from ſinking. Hence it is that vinous fermentation has ſo powerful an effect as a clarifier, (wine being much more limpid than the grape or other fruit juice of which it is made) ſince this proceſs always implies the deſtruction of a portion of ſaccharine mucilage, and the conſequent production of a thin limpid ſpirit.

Coagulating ſubſtances are great clarifiers when mixed with any turbid liquor, the proceſs of coagulation entangling with it all matters merely ſuſpended and not diſſolved, and carrying them either to the *top* in the form of a ſcum, or to the *bottom* in the form of a thick ſediment, according to circumſtances. Thus to clarify muddy cyder, the liquor is beaten up with a ſmall quantity of freſh bullock's blood, and ſuffered to ſtand at reſt for ſome hours, after which the liquor above is as clear as water, and almoſt as colourleſs, and at the bottom is a thick tough cake conſiſting of the coagulated blood which has carried down with it all the opake matter ſuſpended in the liquor. Many other albuminous and gelatinous ſubſtances act in the ſame manner. The effect of white of egg in this way is known to every one. It ſhould be firſt mixed with the turbid liquor (a ſyrup for example) without heat and by agitation. Afterwards on applying leſs than a boiling heat the albumen of the egg coagulates, and carries up with it all the opake particles of the ſyrup, leaving the reſt beautifully clear and limpid.

Sometimes clarification takes place in a very unaccountable manner. Thus it is well known that a handful of marl or clay will clarify a large ciſtern of muddy water, and marl is alſo uſed with advantage in clarifying vinous liquors.[c]

Mere heat will often clarify. Thus the expreſſed juice of cabbage plants is a ſtrong-ſmelling, green, clammy, muddy liquid. By heating, all the turbid matter ſeparates in the form of a green coagulum, and the liquor that remains is almoſt as limpid as water.

Clarification may often be detrimental. In many liquid medicines, ſuch as decoctions of medicinal vegetables and the like, the medicinal portion reſides chiefly in that part which is merely ſuſpended, and therefore when ſeparated by any kind of coagulation, the clear liquor is left nearly inert. See *Filtration*.

CLAY. *Thon*; Germ. *Argille*, Fr.

Any natural earthy mixture which poſſeſſes plaſticity and ductility, when kneaded up with water, is in common language called a *clay*, which term is probably derived from the Latin *glarea* through the medium of the French *glaiſe*. All mineralogiſts however have comprehended within the appellation not only clays properly ſo called, but a few other mineral ſubſtances

[b] Dizé. [c] Parmentier An. Chim. tom. 39.

nearly allied to ſome of the clays, and which become plaſtic by decompoſition. Clay however is by no means a mineral ſpecies ſtrictly ſpeaking, being in moſt caſes, perhaps in all, the reſult of the decompoſition of other minerals. It ſeems adviſable therefore to conſider the property of plaſticity as an eſſential character, and to exclude from the claſs of clays all earthy bodies that are deſtitute of it.

Mineralogiſts have hitherto arranged all the plaſtic clays under two ſpecies, rather from the economical uſes to which they are applied than according to their external characters, compoſition or geological ſituation: the firſt ſpecies is the white infuſible *porcelain clay*, and the ſecond contains all the reſt confounded together, under the general appellation *Potters' clay*. That this mode of arrangement is very defective will be readily allowed, and the reader it is hoped will receive with candour the following attempt at a more ſcientific claſſification.

Eſſential character. *Plaſtic by intimate mixture with water.*

1. *Porcelain clay.*

Its colour is generally reddiſh-white, alſo greyiſh and yellowiſh-white: it has no luſtre nor tranſparency. It occurs either friable or compact; ſtains the fingers; adheres to the tongue; is ſoft but meagre to the feel: is eaſily broken. Sp. gr. about 2.3. It falls to pieces in water, and by kneading becomes ductile, though not in a very great degree. The Corniſh porcelain clay certainly originates from the decompoſition of felſpar, and contains particles of quartz, mica, and talc, from which it is ſeparated by elutriation. The Chineſe kaolin alſo contains mica, and is probably of the ſame origin as the Corniſh. The ſame remark may be applied to the French, &c. It is however by no means certain that all porcelain clay is derived from felſpar, as it varies conſiderably in its compoſition and fuſibility; all the kinds indeed are infuſible at any temperature leſs than a white heat, but ſome, eſpecially the Japaneſe, are refractory in the moſt powerful furnaces. The Corniſh clay, according to Wedgewood, conſiſts of 60 per cent. alumine, and 40 ſilex. That from Limoges in France, according to Haſſenfratz, contains 62 ſilex, 19 alumine, 12 magneſia, 7 ſulphat of barytes. Another ſpecimen of the ſame, analyſed by Vauquelin, gave 55 ſilex, 27 alumine, 2 lime, 0.5 iron, 14 water. A porcelain clay analyſed by Roſe, gave 52 ſilex, 47 alumine, 0.33 iron.

2. *Steatitic clay.*

Its colour is a light fleſh red paſſing into cream colour; its texture is minutely foliated; it has a ſlight ſomewhat greaſy luſtre and takes a poliſh from the nail. It ſtains the fingers, is very friable, and has a ſmooth unctuous feel. When laid on the tongue it diſſolves into a ſmooth pulp without any gritty particles; it is very plaſtic and has a ſtrong argillaceous odour. It occurs in nodules, in a hard cellular hornſtone that forms large mountainous maſſes near Conway in North Wales, and originates from the decompoſition of indurated ſteatite.

3. *Clay from Slate.*

Its colour is aſh-grey paſſing into ochre-yellow: its texture is foliated: it has a ſmooth unctuous feel, and its ſiliceous particles are ſo ſmall as to occaſion ſcarcely any grittineſs between the teeth. It occurs in thin beds on the tops of the ſofter kinds of ſlate-rock, and from its imperviouſneſs to water is always found lining the bottoms of the peat moſſes with which this kind of mountains is generally covered, and in theſe ſituations it is of a white aſh colour, being deprived of its iron and carbon by the acid of the peat. It alſo occurs in thicker beds at the foot of the mountains, but is of a darker colour and leſs plaſtic.

4. *Clay from Shale.*

Its colour varies from greyiſh-blue to bluiſh black: its texture is foliated: it has a ſmooth unctuous feel, takes a poliſh from the nail, is exceſſively tenacious and ductile, and has but a ſlight degree of grittineſs. When burnt it acquires more or leſs of an ochre-red colour: thoſe varieties which are of the deepeſt red uſually contain before burning a portion of ſulphuric acid. It is for the moſt part difficult of fuſion. It occurs abundantly in all collieries, and is produced by the ſpontaneous decompoſition of the ſhale with which the beds of coal are covered. A ſandy clay of a greyer colour and more refractory nature is procured from the decompoſition of the indurated clay that forms the floor of the coal, and is provincially called clunch. The Sturbridge clay from which crucibles, glaſshouſe-pots, &c. are made, is of this kind.

5. *Clay from Trap.*

At the foot of the ſofter rocks of trap-formation, ſuch as wakke, clay-porphyry, and ſome varieties of grunſtein and hornblende rock, are found beds of clay evidently originating from the gradual diſintegration of theſe by the weather. The colour of this clay is generally browniſh grey verging to ochre yellow; it occurs in maſs, is of a compact texture, unctuous, tenacious, gritty and probably is not very infuſible.

6. *Marly clay.*

The colour of this is bluiſh or browniſh red: it occurs either compact or foliated: it has a ſoft unctuous feel, takes a poliſh by friction with the nail, is very plaſtic, more or leſs gritty, though not ſo much ſo as the common alluvial clay. It burns to a brick of a buff or deep cream colour, and at a high heat readily enters into fuſion. It effervesces ſtrongly with acids, and contains from $\frac{1}{4}$ to $\frac{1}{10}$ of carbonated lime. It originates ſometimes from the decompoſition of compact argillaceous limeſtone, but more frequently from the ſofter flaty varieties uſually called ſtone marl. It is largely employed as a manure, and where the calcareous part does not exceed 10 or 12 per cent. it is eſteemed as a material for bricks.

7. *Clay from metallic veins.*

Its colour is grey verging into bluiſh, greeniſh and yellowiſh, or red. It has a ſmooth unctuous feel, is very tenacious, often contains ſulphuric acid and certain metallic oxyds which are never obſerved in other clays, ſuch as lead, ſilver, antimony, copper, and biſmuth. Is found in metallic veins.

8. *Alluvial clay.*

The circumſtances which characterize alluvial clay are the following. It contains a larger proportion of quartzy ſand than the preceding, rounded pebbles of various kinds are alſo imbedded in it; thus ſhowing it to have been carried from its native ſituation and mingled in its progreſs with a variety of extraneous bodies. At leaſt three kinds of it may be diſtinguiſhed, viz. Pipe clay, Potter's clay, and Chalky clay.

Pipe clay is of a greyiſh or yellowiſh white colour, an earthy fracture and a ſmooth greaſy feel: it adheres pretty ſtrongly to the tongue, is very plaſtic and tenacious; when burnt is of a milk-white colour; is difficultly fuſible, though much more ſo than porcelain clay, from which it is further diſtinguiſhed by its ſuperior plaſticity and the ſand which it contains. It is manufactured into tobacco-pipes, and is the baſis of the white or Queen's-ware pottery.

Potters' clay is of a reddiſh, bluiſh or greeniſh colour, has a ſomewhat fine earthy fracture, and a ſoft, often greaſy, feel: it adheres to the tongue and is very plaſtic. It burns to a hard porous red brick, and in a higher heat runs into a dark-coloured ſlag. When tempered with water and mixed with ſand it is manufactured into bricks: thoſe varieties that are the moſt free from pebbles are made into tiles and coarſe red pottery.

Chalky clay is of a leaden blue colour, an earthy fracture and a meagre feel: it is plaſtic, but breaks down by expoſure to the weather. It contains a large proportion of ſand and rounded pieces of chalk of all ſizes up to that of a hazle nut. It effervesces ſtrongly with acids, burns to a red porous brick, and is very fuſible. It is uſed as a manure in the counties of Lincolnſhire, Norfolk, and Suffolk.

CLAY pure. See ARGIL native.

CLAY ſlaty. See SHALE.

CLAYSTONE. *Thonſtein*, Werner.

Its colour is greeniſh, bluiſh, or aſh-grey, or browniſh-red; it is ſometimes marked by browniſh yellow ſpots and ſtripes. It occurs in maſs. Its fracture is fine grained earthy paſſing into even, flaty or ſplintery: ſome varieties are flat conchoidal. It is opake, dull, frangible and ſoft; has a meagre feel and does not adhere to the tongue.

It forms large mountainous maſſes, occurring in beds, veins, and as the baſis of clay porphyry. It paſſes into ſhale and jaſper, and decompoſes into clay.

CLYSSUS OF NITRE. The term *clyſſus* uſed by the old writers in chemiſtry and alchemy is defined to be[a] the vapours that ariſe from the detonation of nitre with any inflammable ſubſtance; the *clyſſus of nitre*, the vapours from nitre and charcoal (for which ſee *Nitrous Acid*), the *clyſſus of ſulphur*, the vapours from ſulphur and nitre, &c. The term is now obſolete, but modern chemiſtry ſtill derives great advantage, in many caſes, from this mode of decompoſition by nitre.

COAGULATION. *Gerinnen*, G.

Coagulation is the ſolidification of a liquid produced without evaporation, and without its aſſuming a cryſtalline form. The ſudden hardening of the white of egg by mere heat is a familiar example of the kind. The term is ſometimes applied alſo to a very ſudden and confuſed cryſtallization, in which the cryſtallized particles appear amorphous to the naked eye, though when examined with a glaſs they exhibit ſome regularity of form. Thus, when ſtrong ſulphuric acid is added to a very concentrated ſolution of potaſh, the whole coagulates immediately to a nearly ſolid maſs of granular cryſtals of ſulphat of potaſh.

COAK. Pit coal deprived of its volatile ingredients by charring in the open air or in an oven, is converted to a light porous ſpungy maſs called coak or cinders. For further particulars ſee COAL.

[a] Macquer. Chem. Dict.

COAL.* *Kohle*, Germ. *Houille*, Fr.

Mineralogiſts are by no means agreed in their arrangement of this important genus of mineral inflammables, we ſhall therefore with the leſs ſcruple differ in ſome degree from them all. It appears to be upon the whole the moſt convenient as well as more conformable to nature to include both the carbonaceous and carbono-bituminous foſſils under a ſingle genus, ſubdividing it into the families of Brown Coal, Black Coal, and Mineral Carbon.

* *Brown Coal.* Imperfectly bituminous; of a brown colour, and vegetable texture.

Sp. I. Bituminized wood. *Ligniform carbonated wood*, Kirw. *Bituminoſes holz*, Werner. *Bois bitumineux commun*, Broch. *Surturbrand*, Iceland.

Its colour is brown approaching to browniſh-black. Its external ſhape exactly reſembles that of compreſſed trunks and branches of trees; its internal texture is preciſely that of wood, retaining not unfrequently even the bark. Its fracture in the ſmall is fibrous, in the great, ſlaty. The principal fracture is glimmering and lighter coloured than the croſs fracture, which is ſhining, and ſometimes imperfectly conchoidal. Its fragments are ſplintery, wedge-ſhaped. It is opake, ſoft, gives a ſhining ſtreak, is ſomewhat elaſtic and flexible, and almoſt light enough to float on water. It burns with a clear flame though with but little heat, and gives out a bituminous odour often mixed with that of ſulphur.

The Surturbrand of Iceland, according to Bergman, contains 58 per cent. of watery and volatile inflammable matter, the carbonaceous and earthy reſidue amounting to 42 per cent. In the bituminized wood of Rollo, Vauquelin found

54.	vegetable earth,
10.7	ſulphat of iron,
0.8	ſulphur,
12.7	oxyd of iron,
0.7	ſulphat of lime,
0.2	ſilex.
79.1	
20.9	loſs.
100.0	

Bituminized wood occurs uſually in alluvial land among the beds of common brown coal; ſometimes alſo forming beds by itſelf: in the Pruſſian amber mines it forms the ſtratum immediately above the amber, and nodules and ſtalactites of this beautiful ſubſtance are generally found intermixed. It is alſo met with in diſperſed fragments in alluvial clay. It abounds alſo in the neweſt floetz-trapformation, and forms maſſes in limeſtone and ſandſtone belonging to the independent coal-formation.

It is found in Britain at Bovey, near Exeter, in the iſles of Skye and Cannay, in the coal ſtrata of Mid-Lothian; in Bohemia and various parts of Germany; in France, Iceland, and Ruſſia.

It paſſes into common brown coal and pitch coal, and is occaſionally penetrated by quartz. It is employed as a fuel, but is greatly inferior to black coal.

Sp. II. Earthy Brown-coal. *Scaly and earthy carbonated wood*, Kirw. *Erdkohle* of Werner. *Bois bitumineux terreux*, Broch.

Its colour is blackiſh or wood-brown or yellowiſh-grey: it occurs in maſs, of a conſiſtence between ſolid and friable. It is without luſtre except when rubbed or cut, and then it becomes ſomewhat ſhining. It ſoils the fingers a little: its fracture is intermediate between uneven and fine earthy. It is very ſoft and falls eaſily to pieces. Sp. gr. a little greater than that of water.

It readily takes fire and burns with a weak flame and diſagreeable bituminous odour. Alcohol when digeſted with it takes up a browniſh bitter ſubſtance, analogous to vegetable extract: by diſtillation it yields a yellow empyreumatic oil, ſoluble in alcohol, and which when deprived of its moiſture by a gentle heat, acquires the conſiſtence of butter or cerate.

It contains from 15 to 20 per cent. of earth and oxyd of iron, the remainder being water and inflammable matter. It often contains pyrites, and then paſſes into the earthy ore of alum, *alaunerde*, which ſee.

It is found in ſimilar ſituations with the preceding ſpecies: in the neighbourhood of Leipſig it occurs in beds from 20 to 40 feet thick, and of great extent.

It is uſed as an inferior kind of fuel, eſpecially in manufactories where a low degree of heat is required; for this purpoſe it is moiſtened with water, well beaten and made into brick-ſhaped maſſes. In the vicinity of Cologne a variety is found of a rich reddiſh-brown colour, which is prepared as a pigment under the name of Cologne umber.

Sp. III. Common Brown-coal. *Compact carbonated wood*, Kirw. *Gemeine braunkohl*, Werner. *Houille brune*, Broch. *Bovey coal.*

Its colour is light browniſh black paſſing into

* Brochant, Kirwan, Jameſon, Hauy.

blackiſh brown. It occurs in maſs: its parallel fracture is fibrous lamellar, paſſing into ſlaty, and is ſlightly glimmering; its croſs fracture is more or leſs conchoidal with a ſhining reſinous luſtre. It acquires a poliſh by friction; is moderately hard. Sp. gr. 1.4 to 1.55; the heavieſt varieties contain pyrites.

It burns readily with a weak flame like half-charred wood and a diſagreeable bituminous odour, and when heated in cloſe veſſels it yields much charcoal; when ignited in an open fire it leaves behind a ſmall quantity of white aſhes. 200 grains, according to Hatchett,[b] yield by diſtillation

60 grains acidulous water,
21 thick brown oily bitumen,
90 charcoal,
29 hydrogen, carburetted hydrogen, and
—— carbonic acid.
200

In England it is found at Bovey near Exeter, and is called Bovey coal: at this place there are ſeventeen ſtrata within the depth of ſeventy-four feet from the ſurface, alternating with alluvial clay: the greateſt thickneſs of the ſeams is between ſix and eight feet. Brown coal is alſo found in the territory of Heſſe, and various other parts of Germany, in Denmark and Greenland, and in Italy.

It is uſed like the preceding ſpecies, for fuel. It paſſes into bituminous wood and moor-coal, ſometimes into pitch-coal.

Sp. IV. Moor coal. *Moorkohle*, Werner. *Houille limoneuſe*, Broch.

Its colour is dark blackiſh brown. It occurs in maſs forming very thick beds, and is characterized by being always full of rifts and crevices. Internally it diſplays a conſiderably reſinous luſtre. Its longitudinal fracture is imperfectly ſlaty, its croſs fracture is even, approaching to flat conchoidal. Its fragments are trapezoidal or rhomboidal. It is tender, remarkably frangible, and light. In its chemical characters it reſembles the preceding ſpecies.

It occurs in alluvial land and in the neweſt floetz-trap-formation. It is met with very frequently in Bohemia, and is alſo found in Tranſylvania and other parts of the Auſtrian dominions, in Denmark and the Faroe iſlands.

** *Black Coal.* Perfectly bituminous; of a black colour.

Sp. V. Slate coal. *Schiefer Kohle*, Werner. *Houille ſchiſteuſe*, Broch.

Its colour is perfect black paſſing into greyiſh-black, and often preſents more or leſs of an irridefcent tarniſh. It occurs in maſs and generally poſſeſſes a high reſinous luſtre. Its principal fracture is ſtrait ſlaty, the croſs fracture is ſmall-grained uneven, paſſing into flat conchoidal. It breaks into indeterminately angular or trapezoidal fragments. It is ſoft and eaſily frangible. Sp. gr. 1.25 to 1.4. It contains from 57 to 64 per cent. of carbon, from 33 to 43 of bitumen, being a mixture of maltha and aſphalt, and from 3 to 6 per cent. of earth and oxyd of iron. It runs into the two following varieties.

Var. 1. Foliated coal. *Blatterkohle*, Werner. *Charbon lamelleux*, Broch.

This differs from the preceding in having a ſomewhat higher luſtre, and a ſtrait foliated longitudinal, and ſlaty croſs fracture. It is alſo ſofter and more ſubject to decompoſition.

Var. 2. Coarſe coal. *Grobkohle*, Werner. *Houille groſſiere*, Broch.

The croſs fracture of this diſplays a coarſer granular texture than common ſlate-coal; its colour is not ſo pure a black, it poſſeſſes leſs luſtre, is conſiderably harder, and its ſp. gr. on account of the greater quantity of earth that it contains, amounts to about 1.5.

Moſt of the common coals belong to this ſpecies, and from the different phenomena which they exhibit during combuſtion, a great number of varieties are known in the market, and are ſufficiently obvious to an experienced eye, which yet cannot be deſcribed.

The two points which are principally to be attended to with regard to common coals, in an economical point of view, are the intenſity of the heat and the duration of the combuſtion, and theſe are chiefly influenced by the proportion of aſphalt which they contain. Coals in which the bituminous part is chiefly maltha, with only a ſmall quantity of aſphalt, kindle very eaſily, burn briſkly and quickly with a bright blaze, cake but little, require no ſtirring, and by a ſingle combuſtion are reduced to looſe aſhes, ſuch are the Lancaſhire coals, the Scotch and moſt of thoſe which are raiſed on the weſtern ſide of England. Thoſe on the other hand in which aſphalt prevails kindle difficultly, and after lying ſome time on the fire become ſoft and in a ſtate of almoſt ſemifuſion; they then cohere or cake, ſwell conſiderably, and throw out on every ſide tubercular ſcoriæ accompanied by bright jets of flame. In conſequence of the coheſion and tumefaction of the coals, the paſſage of the air is interrupted, the fire burns

[b] Phil. Tranſ. for 1804.

hollow and would be extinguiſhed if the top were not broken in from time to time. The produce of aſhes is ſmaller than in the free burning coals, the greater part of them being mixed with the carbonaceous part of the coal and forming grey ſcoriæ, commonly known by the name of cinders, which being burnt again with freſh fuel give out an intenſe heat, and are ſlowly reduced, partly to heavy aſhes and partly to ſlag. The beſt coal of Northumberland Durham and Yorkſhire is of this kind: it burns longer and gives more heat than the preceding, and in general bears a higher price.

Slate coal is found principally in the independent coal-formation, and is the moſt widely diffuſed of any of the ſpecies. It is often mixed with pyrites, and penetrated by thin veins of quartz or calcareous ſpar.

Sp. VI. Pitch coal. *Pechkohle*, Werner. *Houille piciforme*, Broch.

Its colour is velvet black paſſing ſometimes into browniſh black. It occurs in maſs, in plates, and ſometimes in the ſhape of branches with a regular woody ſtructure. It has a brilliant reſinous luſtre, and a perfectly conchoidal fracture; the ſurfaces of the natural joints are nearly ſpecular: its fragments are indeterminate ſharp-edged. It is ſoft and brittle. Sp. gr. 1.3.

It burns with a greeniſh flame and a ſtrong bituminous ſmell, and leaves behind a light yellowiſh coloured aſh. It occurs principally in the neweſt floetz-trap coal-formation. It is uſed as fuel, but the finer and harder pieces are worked into various trinkets, and go under the name of jet. It occurs in detached fragments in the Pruſſian amber mines, and is there called black amber.

Sp. VII. Cannel coal. *Kennelkohle*, Werner. *Houille de Kilkenny*, Broch. (This mineralogiſt however is entirely in an error in ſuppoſing cannel and Kilkenny coal to be the ſame, the latter of theſe being a variety of Glance coal. See ſpecies 8.)

Its colour is dark greyiſh black. It occurs in maſs: has a gliſtening reſinous luſtre. Its longitudinal fracture is flat conchoidal, its croſs fracture is perfectly conchoidal. When cut with a knife it exhibits a ſhining luſtre, and the cut ſurface is full of very minute conchoidal fractures, giving it a porous appearance. It is brittle, but is the moſt difficultly frangible of all the coals. Sp. g. 1.23. It is very inflammable, and crackles and flies while burning, eſpecially if it is not laid in the direction of the croſs fracture: it flames much and burns quickly, but does not cake, and leaves behind from 3 to 4 per cent of aſhes.

The ſplent coal of Scotland is an inferior variety of cannel: its principal fracture is flaty, its croſs fracture imperfectly conchoidal; its ſp. gr. 1.42. It contains pyrites, and leaves about 21 per cent. of aſhes.

Cannel coal occurs in the independent coal-formation. It is found in great plenty and remarkably pure at Wigan in Lancaſhire, and occaſionally in moſt of the other Engliſh collieries.

The ſplent coal abounds at Gilmerton, near Edinburgh.

Its chief uſe is as a fuel, but the pureſt Wigan cannel will bear to be worked in the turning lathe, from which it receives a high poliſh: hence it is ſhaped into various ornamental utenſils, and when cut into beads is not to be diſtinguiſhed from jet.

* * * *Mineral Carbon.* Deſtitute of bitumen; conſiſts of charcoal, with various proportions of earth and iron.

Sp. VII. Mineral charcoal. *Mineraliſche Holzkohle.* Werner.

Its colour is greyiſh black. It occurs in plates and irregular pieces. It has a glimmering ſilky luſtre, and a fibrous fracture diſcovering its ligneous texture. It ſoils the fingers, is ſoft and friable. It is ſomewhat heavier than common charcoal, and is eaſily reduced to aſhes before the blowpipe without flaming.

It occurs in thin layers in brown coal, ſlate coal, flaty glance coal, and pitch coal, but in too ſmall quantities to be made any ſeparate uſe of.

Sp. VIII.. Glance coal.

Of this there are three varieties.

Var. 1. Conchoidal glance coal. *Muſchliche glanzkohle*, Werner. *Houille eclatante*, Broch.

Its colour is iron-black, inclining to brown. It occurs in maſs and veſicular, the interior of the veſicles has a ſteel blue tarniſh. It has a bright ſhining metallic luſtre, and a perfectly conchoidal fracture. Its fragments are indeterminately angular, and ſharp-edged. It is moderately hard, frangible and light.

It burns without flame or ſmell, and leaves a white aſh. That from Heſſe has been analyzed, and contains

96.66	charcoal
2.	alumine
1.33	oxyd of iron
99.99	

It is of rare occurrence, having been met with only in the Meiſſner in Heſſe, and at Newcaſtle.

Var. 2. Columnar glance coal. *Stangenkohle*, Werner. *Houille fcapiforme*, Broch.

Its colour is dark greyish black, sometimes verging to brownish black, the sides of its natural divisions are often covered with a yellow ferruginous earth. It occurs in masses. It possesses a shining lustre, between resinous and metallic. Its fracture is more or less perfectly conchoidal. It always occurs in thick, curved, parallel, columnar, distinct concretions, having smooth glimmering surfaces. It is soft, very easily frangible and light.

It burns without flame or smell, and leaves a greyish white ash. It has hitherto been only found at the Meissner in Hesse, where it occurs together with other coal in the newest floetz-trap-formation.

Var. 3. Slaty glance coal. *Schiefrige glanzkohle*, Werner. *Kohlenblende* of Broch. Emmerl. and Wiedenm. *Anthracite*, Hauy and Dolomieu. *Kilkenny coal. Welsh culm.*

Its colour is dark iron black, verging on steel-grey. It occurs in mass: has a bright metallic lustre: its principal fracture is more or less curved slaty, its cross fracture is small and imperfectly conchoidal. It breaks easily into indeterminate angular fragments. Sp. gr. 1.5 to 1.8.

When pulverized and heated on a muffle it becomes red, and slowly consumes, with a very light lambent flame, without smoak; it does not cake, and when pure emits no sulphureous or bituminous odour: it leaves a variable proportion of reddish ashes, and the unconsumed particles retain their original colour and lustre.

The Kilkenny coal is somewhat harder than is customary with this variety, it possesses a very brilliant lustre, which by long keeping is impaired, in consequence of a light olive tint which overspreads it from decomposing pyrites. Some kinds being nearly pure burn without any smell, but it often gives out a strong sulphureous odour. Those specimens that abound in pyrites also contain mineral charcoal.

Slaty glance coal consists of carbon, with from 3 to 30 per cent. of earth and iron: the following are the principal analyses which have been made of this substance.

	Vauquelin		Dolomieu		Panzenberg	
Carbon	68	—	72.05	—	90	90
Silex	30	—	13.19	—	2	4
Alumine	—	—	3.29	—	5	4
Oxyd of iron	2	—	3.47	—	3	2
	100		92.00		100	100

This mineral occurs in imbedded masses, beds and veins in primitive, transition, and floetz rocks. It is found in gneiss, in micaceous and argillaceous schistus, in mineral veins, with calcareous spar, native silver, mineral pitch, and red iron ore, and has been discovered by Jameson in the independent coal-formation in the Isle of Arran.

Sp. IX. Plumbago. *Graphit*, Werner. *Graphite*, Broch. *Fer carburé*, Hauy. *Black-lead.*

Its colour is dark iron black, passing into steel-grey. It occurs in mass, in kidney-shaped lumps, and disseminated. It has a glistening metallic lustre: its fracture is small somewhat curved foliated approaching to scaly, or granular uneven; in the great it is slaty. It occurs generally in granular or scaly distinct concretions: it takes a polish by cutting or rubbing, gives a dark lead-grey streak, is unctuous to the feel, soft, and not very brittle. Sp. gr. 1.98 to 2.26.

When heated it does not flame, nor can it support combustion by itself. After long exposure to a high heat on a muffle its carbon is burnt off, and its earthy and metallic part remains behind.

The purer kind of plumbago, according to Scheele and Berthollet, consists of about 90 per cent. of carbon and 10 of iron. An impure kind from Pluffier afforded Vauquelin

23	carbon
2	iron
37	alumine
38	Silex
100	

It is found in primitive and transition rocks in England, Scotland, France, Spain, Germany, &c.

Its most important use is as a material for pencils to write or draw with, for which purpose none that has yet been discovered is comparable to that from Borrowdale in Cumberland: it is sometimes used to lubricate machinery with instead of oil; also to protect iron from rust, and, when mixed with clay, as a material for crucibles.

Modern mineralogists distinguish three different kinds of coal-formation, or three series of rocks entirely different from each other, which contain coal; and as a knowledge of these is important both in an economical point of view, and to enable us to form a just theory concerning the origin of this interesting mineral,

we ſhall give a ſhort account of the principal facts that are aſcertained on this ſubject.

The independent or true coal-formation conſiſts eſſentially of extenſive parallel ſtrata of coal, covered by ſtrata of ſhale, which contain impreſſions of vegetables, and ſometimes the remains of freſh-water ſhell-fiſh. Beneath each ſtratum of coal is generally a ſtratum of ſomewhat greaſy indurated clay, called by the miners *clunch*, which is uſually, if not always, deſtitute of thoſe organic remains that characterize the ſhale. It rarely happens that the ſlate belonging to an inferior ſtratum of coal is in immediate contact with the clunch of a ſuperior ſtratum, the coal ſeams being generally ſeparated from each other by beds of various coloured ſandſtone, of clay, of bituminous ſhale, of ratchil or rubble-ſtone, of a ſoft decompoſing clay porphyry, or grünſtein, called by the Engliſh miners rotten-ſtone, of argillaceous iron ore, of marl, and of ſecondary limeſtone. Sometimes one, often ſeveral of theſe ſtrata interpoſe between the ſeams of coal in irregular alternation, and there are extenſive collieries in which ſome of them, eſpecially the limeſtone, are entirely wanting. The number of ſeams of coal in any particular formation or coal-field is extremely variable; it ſeldom however happens that there are more than three or four worth the expence of working. The uppermoſt ſeam is generally ſhattery, and very much mixed with earth and pyrites. The parallelism of the various ſtrata is for the moſt part very exactly preſerved, though where a very thick bed of ſandſtone occurs, the ſtrata above and below it have not always the ſame parallel. The general poſition of the beds in the independent coal-formation is ſcarcely ever horizontal, and never vertical, though occaſionally forming an angle of about 75°. The regularity of the dip, however, is frequently interrupted by partial diſruptions, ſlips, and ſinkings of the ſtrata, emphatically called by the miners *troubles*, which appear like great cracks and are filled with ſand, gravel, clay, &c. and afford a free paſſage for the water. Sometimes the ſtrata are divided by vertical walls of baſalt, riſing from an unknown depth to the ſurface, and of vaſt length; theſe are called by the miners *dykes*, and differ from the ſlips in being impermeable to water, and in ſimply dividing the ſtrata without altering their direction: both the ſlips and the dykes however are obſerved to ſhatter and pulverize, and decompoſe the coal in their immediate vicinity. The particular ſpecies that are found in the independent formation are ſlate coal, with its varieties, cannel coal, and ſometimes pitch-coal. Almoſt all the Engliſh coals, and thoſe in the neighbourhood of Liege, are found in this formation.

The ſecond coal formation is characterized by the neweſt floetz-trap. In this the ſtrata are not ſo numerous nor ſo perfectly parallel as in the former. The coal is not covered with ſhale, but with clay or baſalt, in which are found neither vegetable impreſſions nor animal remains. The beds which compoſe this formation are wakke, baſalt, both amorphous and columnar, grünſtein porphyry, and argillaceous iron ore. Slips or diſruptions of the ſtrata are not common in this formation, but dykes are of frequent occurrence. The ſpecies of coal which it contains are principally pitch-coal, alſo moor and glance coal, and ſometimes ſlate-coal. The chief collieries of Scotland, thoſe of Auvergne and the central parts of France, of the Meiſſner in Heſſe, and the Mittelgebirge in Bohemia are examples of this formation.

The third coal-formation occurs in alluvial land, and poſſeſſes many characters that diſtinguiſh it from the preceding ones. The only ſtrata which are found in it, are clay, ſand, and gravel. The ſeams of coal do not preſerve the ſame thickneſs through the whole of their extent, nor is the parallelism of the earthy ſtrata by any means regular, ſudden elevations and depreſſions in the ſame ſtratum, frequently taking place. There are no ſlips or dykes in this formation, and every appearance concurs to prove its very recent origin. The ſpecies of coal that it contains belong chiefly to the brown-coal family, namely bituminized wood, earthy and common brown-coal, moor-coal, and rarely pitch-coal.

The ſigns of coal are very uncertain both in the floetz-trap and alluvial formations. In the firſt of theſe no appearance is to be depended on except the actual outburſt of coal, or of a bed of clay, containing fragments of coal. In the ſecond, the only probable indication is clay, with branches and trunks of trees: petrified wood is often found in conſiderable quantity in *ſandſtone* ſtrata, without there being the ſlighteſt probability of a bed of coal beneath.

The independent coal-formation has however more numerous ſigns, and thoſe better to be depended on. Being the oldeſt of the three formations it is ſituated nearer the primitive and tranſition rocks than the others, and in general appears to rank immediately after ſecondary limeſtone: where beds of this adjoin, and reſt upon ſlate, as is frequently the caſe in the

northern and weſtern parts of England, the independent coal-formation is generally obſerved within a little diſtance of the limeſtone on the oppoſite ſide to the ſlate-rock, and therefore divided from it by the limeſtone. The extenſive collieries of Flint, Ruabon and Chirk in North Wales, of Glamorganſhire in South Wales, of Coalbrook-dale in Shropſhire, and Kingſwood, near Briſtol, are all examples of this, all of them commencing immediately in the vicinity of ſecondary limeſtone, which itſelf on the oppoſite ſide may be traced into ſlate: in ſome of theſe inſtances the limeſtone does not exceed a few hundred yards in width, while in others it amounts to ſeveral miles. Among the ſtrata of which the coal-formation itſelf is compoſed, limeſtone, clay, and marl, are the leaſt certain indications, as theſe are met with moſt frequently in formations unconnected with coal. White micaceous ſandſtone, eſpecially when in thin layers is a promiſing ſign: argillaceous iron is ſtill more ſo; but ſhale with vegetable impreſſions, or the tenacious blue clay into which it decompoſes, is the ſtrongeſt indication of all: there are few ſituations in which this ſhale or clay occurs where an accurate ſearch will not diſcover detached fragments of coal, and often the crop or outburſt of the ſeam itſelf; and even ſhould theſe be wanting, it will be well worth while to employ the borer and pierce through the ſhale, immediately beneath which a ſeam will be found, if it belongs to the coal-formation.

From the vegetable remains with which the ſhale that lies upon coal is always filled, from the ligneous texture which may be traced here and there, even in the moſt compact ſpecies of coal, and from the regular and gradual tranſition of bituminized wood through pitch coal, and ſlate coal, into glance coal, it is now generally ſuppoſed that all coal (plumbago excepted) is of vegetable origin. As to the preciſe mode and agent by which the proceſs of bituminization has been brought about, the manner in which, and the period when the ſucceſſive ſtrata of the coal-formations have been depoſited, there exiſts and probably ever will exiſt, various theories more or leſs ingenious and conſiſtent, which although in all likelihood very remote from the truth are valuable as exciting to further enquiry, and as convenient methods of arranging and collecting many very curious and important facts. To enter into the detail of theſe, however, would be deviating too far from the practical objects of the preſent work.

The great uſe of coal is as a material for fuel, and it is uſed either in its crude ſtate, or after it has been converted into coak by a proceſs analogous to that by which wood is made into charcoal.

Unprepared coal is employed in all manufactures in which liquids are to be boiled or evaporated, ſuch as brewing, ſalt-making, diſtilling, and dying; it is uſed alſo in this ſtate by glaſsmakers, blackſmiths, and limeburners, and in all metallurgical proceſſes in the large way, where fuſion is performed in a reverberating furnace. As a domeſtic fuel alſo it is uſed for the moſt part without any preparation; but in ſome places where coal cannot readily be procured, it is reduced by pounding, to the conſiſtence of ſmall gravel, and worked up with an equal weight of tenacious clay, and moulded into balls of the ſize of the fiſt. Theſe being firſt well dried in the air are made uſe of as fuel, and are found to burn longer and give out more heat than the coal would do without this addition. The only inconvenience attending theſe balls is, that they do not readily inflame, and therefore it is neceſſary at the kindling the fire to employ common coal, and not to add the balls till a ſufficient body of fire has been collected.

In blaſt furnaces, and the upright ſmelting furnaces for iron and copper, coal cannot be uſed in its crude ſtate, both becauſe its ſulphureous vapours would injure the quality and diminiſh the quantity of metal, and becauſe by its caking the current of air would be obſtructed, and the whole proceſs thrown into diſorder: neither can this combuſtible be employed, except in the ſtate of coak, for drying malt and other ſimilar proceſſes in which ſmoaky fuel would be extremely prejudicial. Coal is deprived of its bitumen and other volatile parts, or in other words is made into coak, in various ways. The ſimpleſt mode is to diſpoſe it in beds, from 40 to 60 yards long about ſix feet wide and three feet high, in the open air, and kindling it in various parts, to allow the combuſtion to proceed till the maſs is of a glowing red and ceaſes to ſmoke: being now taken to pieces and ſpread abroad the fire ſoon goes out, and the reſidue is found to be a light ſpungy ſcoriform ſubſtance (technically called coak or cinders) not ſo eaſily inflammable as coal, but when once kindled giving out an intenſe heat without either caking or ſmoaking. The above is apparently a very waſteful proceſs, not only becauſe the volatile matters are allowed to eſcape, but by this free expoſure to the air a conſiderable portion of the carbonaceous part is alſo loſt: it has however

this advantage, that the ſulphur is at the ſame time entirely got rid of, which cannot be done by cloſe diſtillation, and in conſequence the fuel is much better fitted for thoſe purpoſes in which the preſence of ſulphur would be detrimental: for this reaſon doubtleſs it is that all the coak conſumed in the numerous iron forges of this country is thus prepared. Another method of charring coal is to burn it in large vaulted ovens till it ceaſes to flame: this is more economical than the former, both becauſe the product of coak is greater, and becauſe the ſlack or ſmall coal of the caking kinds may be employed for this purpoſe; all the volatile parts however are loſt, and the coak is not entirely deſulphurated.

In the county of Saarbruck on the Rhine, are ſome eſtabliſhments for making coak and lamp-black at the ſame time, which perhaps might be found worthy of imitation in this country. The furnace [c] is a long cylinder of brick-work placed ſomewhat in a ſlanting direction, terminated at the lower-end by a grate and regiſter door, and opening at the other extremity into a large vaulted chamber: the firſt chamber communicates with a ſecond ſimilar to it, except that it is ſmaller, and this latter by means of an aperture in the ceiling opens into a chimney, a ſack of looſely woven cloth being interpoſed. The proceſs begins by lighting a fire in the furnace and ſupplying it gradually with coals, till the furnace is about half full, then by means of the regiſter in the door, a ſmall current of air is admitted till the coals ceaſe to ſmoke; at this period the door is opened and the contents of the furnace are raked into a hole below its mouth, where they are extinguiſhed, leaving however in the furnace a ſufficient quantity of lighted coals to kindle the next charge. While the coals are thus charring the ſmoke paſſes into the large chamber, where it depoſits the greateſt part of its ſoot, and the reſt is collected in the ſmall chamber, and in the ſack which covers the opening into the chimney. By a careful regulation of the draft it appears probable that the coal might be as completely deſulphurated, and with as little loſs as in the open air, and the lamp-black would be nearly a clear gain: 100 lbs. of coal thus treated afford about 33 lbs. of coak, and 3½ of lamp-black.

Coal, when heated in cloſe or nearly cloſe veſſels, affords a vaſt quantity of a highly inflammable gas (already deſcribed as a variety of Carburetted Hydrogen) of Coal-Tar, or Petroleum, and of impure carbonated ammonia. From a laudable deſire of ſaving the two latter valuable products, which had hitherto been allowed to eſcape in the proceſs of coaking, Lord Dundonald erected ſome years ago at Coalbrook-dale, and we believe elſewhere, a ſeries of buildings to ſerve as a kind of diſtillatory apparatus, in which he prepared coak, and at the ſame time collected the petroleum and ammonia diſengaged in the proceſs: his ſucceſs was complete, as far as the diſtillation was concerned, but the undertaking was ſhortly abandoned in conſequence, as we underſtand, of the ſulphur contained in coak thus made, which rendered it unfit to be uſed in the furnaces. Indeed it is manifeſt, that in order to decompoſe the pyrites with which all coal more or leſs abounds, it is neceſſary to expoſe it while burning to ſuch a ſtream of air as ſhall deſtroy both the petroleum and ammonia, and leave no opportunity for the exertion of economical ingenuity, except in the collection of ſoot and increaſing in ſome degree the product of coak.

COATING, or *Lorication*. See Cements.

COBALT. *Cobalt*, Fr. *Kobalt*, Germ.

Cobalt when pure is a metal of a white colour inclining to bluiſh or ſteel-grey, when tarniſhed acquiring a reddiſh tinge: its fracture is compact, fine-grained uneven. At the common temperature it is brittle and pulverizable, but when red hot will bear to be in ſome degree extended under the hammer. Its ſpecific gravity is=8.53. It is attracted by the magnetic needle, and is itſelf capable of polarity. It requires for its fuſion nearly the ſame intenſity of heat as caſt iron does. When in the ſtate of oxyd it tinges the ſaline vitreous fluxes of a deep blue colour. It is ſoluble in nitro-muriatic acid, and the diluted ſolution forms a blue ſympathetic ink. It occurs, 1. mineralized by arſenic; 2. as an oxyd; 3. combined with arſenic acid; 4. combined with ſulphuric acid.

Sp. I. Arſenical Cobalt. [a]

Cobalt is never found pure in the metallic ſtate, but is always alloyed with arſenic, and often contains beſides a variable portion of iron and ſulphur, beſides which it is occaſionally mixed with nickel, biſmuth and ſilver. The amorphous ſub-ſpecies have none of them been ſubjected to an accurate analyſis, but the cryſtallized has been examined both by Klaproth and Taſſaert. The former chemiſt obtained from the bright white cobalt of Tunaberg.

(3d ſub-ſpecies)

[c] Journ. des Mines. No. 55, p. 487.

[a] Emmerling, Widenmann, Hauy, Kirwan, Brochant.

44	Cobalt
55.5	Arſenic
0.5	Sulphur
100.0	

The latter procured from the ſame variety,

36.66	Cobalt
49.	Arſenic
5.66	Iron
6.5	Sulphur
97.82	
2.18	Loſs
100.	

Similar differences are obſervable between the analyſis of this variety by other chemiſts, ſo that it may be conſidered as allowing of a conſiderable range both in the proportion and nature of its conſtituent parts, without materially affecting its cryſtallization. It appears however from Hauy, that when the cryſtals diſplay a lamellar fracture they contain a notable proportion of ſulphur and iron. Kirwan, Hauy and others, form two ſpecies of cobalt ore according to the preponderance of arſenic or pyrites in their compoſition. Brochant and the later German mineralogiſts on the other hand form three ſpecies. This latter arrangement appears the moſt uſeful and exact, but as there are in reality no certain ſpecific characters, we ſhall conſider the whole as one ſpecies with three ſubdiviſions.

1. Sub-ſpecies. White Cobalt. *Weiſſer Speiſkobolt. Cobalt blanc.* (Species 2d. of Kirw. and Hauy.)

The colour of this mineral when recently broken is tin-white, but its ſurface is generally yellowiſh, bluiſh, reddiſh, or greyiſh, or irideſcent like ſteel that has been heated. It occurs in maſs, diſſeminated, kidney-ſhaped, and rarely in minute quadrangular tables, or imperfect cubes and octahedrons. Their external luſtre is ſlight, but internally is brilliant and metallic. Its fracture is fine-grained, uneven: when broken, it flies into ſharp-edged irregular fragments. When in maſs it contains fine-grained granular diſtinct concretions. It acquires a poliſh by friction, is brittle and hard. When expoſed to the blow-pipe white cobalt melts with great facility, giving out at the ſame time a white vapour and ſtrong arſenical odour, a white brittle bead of metal remaining behind which communicates a blue colour to glaſs of borax.

It is found in Norway, at Tunaberg in Sweden, Annaberg in Saxony, alſo, though rarely, in Swabia and Stiria. In Saxony and Norway it is contained in beds of micaceous ſchiſtus accompanied by the red earthy cobalt, quartz, hornblende and pyrites.

2. Sub-ſpecies. Dull-grey Cobalt. *Grauer Speiſkobolt. Cobalt gris* (Sp. 1. of Kirw. and Hauy.)

The colour of this mineral is a clear ſteel grey, but by expoſure to the air it acquires an irideſcent tarniſh. It occurs in maſs or diſſeminated, ſometimes in kidney-ſhaped or cluſtered maſſes, and very rarely in ſpecular laminæ. Its external luſtre is very feeble, but internally it exhibits a bright metallic luſtre. Its fracture is compact, generally even, but ſometimes paſſing into flat conchoidal; its grain is remarkably fine and cloſe. Its fragments are ſharp-edged, indeterminate. It is not ſo hard as the preceding, and is leſs brittle. Its ſpecific gravity varies from 4.3 to 5.3 or even 5.5. It gives a bluiſh-grey metallic ſtreak.

When expoſed by itſelf to the blow-pipe it gives out an arſenical vapour and ſmell, but ſeldom fuſes: when treated in the ſame way with borax it gives the flux a blue colour, and is reduced to a metallic globule.

A ſpecimen of this from Cornwall was analyzed by Klaproth, who procured from it about 20 per cent. of cobalt, 24 of iron, and 33 of arſenic, the remainder conſiſting partly of biſmuth and ſulphur, together with earthy matter; ſome varieties have alſo been found to contain nickel and ſilver.

It is ſomewhat rarer than the following ſubſpecies, but is found at Schneeberg, Freyberg, and other places in Saxony, at Joachimſthal in Bohemia, Wittichen in Swabia, and Schmoëlnitz in Hungary; alſo in Stiria, at Allemont in France, in Norway, and in Cornwall. It is generally accompanied by other cobaltic ores, by kupfernikel, native biſmuth, and ſilver.

3. Sub-ſpecies. Bright white Cobalt. *Glanz Kobolt. Cobalt eclatant* (Sp. 2. of Kirw. and Hauy.)

The colour of this mineral is tin-white, but tarniſhes to greyiſh, yellowiſh, or irideſcent. It is found in maſs, or diſſeminated or inveſting; or of particular ſhapes as cluſtered, reniform, globular, interlaced, in ſpangles; or cryſtallized in cubes or octahedrons. The cryſtals are of middling ſize or ſmall, their ſurface is com-

monly ſmooth and brilliant, and marked with ſtriæ on the ſides of the primitive cube.

The fracture of the cryſtals is lamellar, that of the other varieties is fine-grained uneven, or radiated. When in maſs it preſents granular, or teſtaceous, or lamellar diſtinct concretions. In hardneſs it is ſomewhat inferior to the preceding ſub-ſpecies; when pulverized it is of a ſteel-grey colour. Sp. gr. 6.2 to 6.3. It is brittle and eaſily broken.

When expoſed to the blow-pipe it burns with a faint white flame, diſengaging arſenical vapours; it then becomes black, is attractable by the magnet, and is with the utmoſt difficulty reduced to a metallic globule. It often affords as much as 50 per cent. of reguline cobalt.

This is the commoneſt of all the ores of cobalt: it occurs for the moſt part in primitive mountains, together with the other ſpecies of cobalt ore, with vitreous, red, and native ſilver, with arſenical and cupreous pyrites, &c. It is met with in many parts of Germany, but eſpecially in Saxony and Bohemia, at Tunaberg in Sweden, at Modun in Norway, in the Pyrenees, in Stiria, and in Cornwall.

Species II. Earthy Cobalt. Of this there are the four following varieties.

Var. 1. Friable black cobalt, *Schwarzer Kobolt mulm. Cobalt terreux noir friable.*

The colour of this is black, bluiſh, browniſh or greyiſh black. It has no luſtre, is of a looſe earthy conſiſtence, friable and meagre; it ſtains the fingers in a ſlight degree, and gives a brightiſh ſtreak. It is ſoluble in muriatic acid, tinges borax blue, and very rarely betrays any ſulphureous or arſenical ingredient when treated with the blow-pipe.

Var. 2. Indurated black Cobalt. *Verhærteter ſchwarzer Kobolt. Cobalt terreux noir endurci.*

In colour it reſembles the former, except that it is ſometimes of a dark greeniſh black. It occurs maſſive, diſſeminated, inveſting, kidney-ſhaped, cluſtered or in veins. It is dull, but takes a poliſh by friction. Its fracture is earthy and compact, paſſing into flat conchoidal. It poſſeſſes a moderate degree of hardneſs. Sp. gr. from 2. to 4. With nitric acid it gives a red ſolution, and a bluiſh green one with muriatic acid. It has not been accurately analyzed, but conſiſts of oxyd of cobalt with a ſmall variable proportion of arſenic and ſulphur mixed with vitreous ſilver ore, oxyd of iron and clay.

This and the preceding variety are always found together, but the indurated is by much the moſt rare. It is found in Saxony, Thuringia, Swabia, and Tyrol.

Var. 3. Yellow Cobalt. *Gelber Erdkobolt. Cobalt terreux jaune.*

Its colour is that of faded ſtraw, paſſing into greyiſh-white and often ſtreaked with brick-red. It is found in maſs, diſſeminated, or inveſting. It is without luſtre, has a fine-grained earthy fracture, gives an unctuous ſtreak, is ſoft and friable.

It is infuſible *per ſe*, gives a feeble arſenical odour, and communicates a deep blue tinge to borax: but when mixed with iron, as it often is, the colour is greeniſh.

This is one of the rareſt of the ores of cobalt: it has hitherto been found only at Saalfeld in Thuringia, Alpirſbach in Wirtemberg, and Allemont in Dauphiné.

Var. 4. Brown Cobalt. *Brauner Erdkobolt. Cobalt terreux brun.*

Its colour is a clear liver-brown paſſing into grey, yellow, and black. It occurs in maſs or diſſeminated; it is dull, but acquires a greaſy luſtre by friction. Its fracture is fine-grained earthy. It is eaſily broken, being almoſt friable. It has not been analyzed, but appears to be the connecting link between the ſecond and third varieties. When thrown on burning coals it generally gives out an arſenical odour.

Sp. III. Red Cobalt. Of this there are two varieties.

Var. 1. Cryſtallized. *Koboltblute. Fleurs de Cobalt.*

The uſual colour of this mineral is peach-bloſſom red, paſſing into cochineal and greyiſh-red; by expoſure to the air it becomes paler and almoſt white. It is found very rarely in maſs or diſſeminated, and ſtill ſeldomer cluſtered or kidney-ſhaped: its moſt uſual ſtate is that of a thin cryſtalline covering, or minute druſes of cryſtals. The forms which it generally affects are rectangular tables, or tetrahedral acicular priſms, or hexahedral priſms terminated by dihedral ſummits: theſe figures however are not often determinable on account of the minuteneſs of the cryſtals, and their tendency to form radiated and globular groups. The ſurface of the cryſtals is ſmooth and brilliant, and their fracture lamellar. The fracture of the other kinds is radiated paſſing into fibrous. It is tranſlucid, and often when cryſtallized ſemitranſparent.

Before the blow-pipe it gives a faint arſenical odour, and becomes of a dark grey colour, it is almoſt infuſible by itſelf, and gives a beautiful blue tinge to borax.

Var. 2. Earthy. *Koboltbeſchlag. Cobalt terreux rouge pulverulent.*

The colour of this is the ſame as that of the preceding variety. It occurs in a pulverulent or indurated ſtate, diſſeminated through or inveſting other minerals, and occaſionally in maſs. It is dull, opake, and has an uneven earthy fracture. In other reſpects it agrees with the preceding.

Sp. IV. Native Sulphat of Cobalt. *Natürlicher Koboltvitriol. Sulfate de Cobalt natif.*

At Herrengrund, near Neuſohl in Hungary, is found a ſaline ſubſtance in the form of tranſlucid ſtalactites of a pale roſe red colour: it was at firſt ſuppoſed to be ſulphat of manganeſe, but from an analyſis by Klaproth it appears to be a pure ſulphat of cobalt.

Reduction of the Ores and Analyſis.

Cobalt is never employed in the reguline ſtate for any purpoſe of manufactory, the ſole uſe of this valuable metal being to give various ſhades of blue colour to glaſs, porcelain, and other earthy mixtures, and when thus employed it muſt be in the ſtate of oxyd. But the intenſity of colour given by the oxyd in very ſmall proportion is ſo great that it is found more convenient, after due calcination, to mix and dilute it with a quantity of vitrifiable earth, and in this ſtate it is generally ſold, that is, either ſimply mixed with earth, when it appears as a brown gritty powder called *Zaffre*, or elſe already melted with a portion of vitrifiable materials when it becomes a glaſs of a moſt intenſe blue colour, which, when properly ground and ſifted, forms the *Smalt* of the ſhops.

The preparation of theſe two articles of commerce will be mentioned, after the analyſis of the cobalt ores has been deſcribed.

Many of theſe ores are complicated and difficult to analyze. The natural metallic admixtures with cobalt hitherto diſcovered are the following:

1. Arſenic, generally in very large quantity, part of which is in the ſtate of reguline arſenic, and as it appears, another part is in the ſtate of arſenic acid, or at leaſt is brought to this ſtate in the proceſs of analyſis. This unites with part of the cobalt forming an arſeniat of cobalt, which has often been miſtaken for the pure oxyd. The entire ſeparation of the two is attended with much difficulty.

2. Nickel is abundantly mixed with many of the cobaltic ores, and not eaſily ſeparated, being ſoluble in the ſame menſtrua.

3. Iron, in variable quantity, generally adheres to the natural cobalts, and is a hurtful ingredient, as it much alters and impairs the beautiful blue colour for which alone cobalt is valued.

4. Manganeſe, which now and then is mixed with the cobalt ores, has a ſtill worſe effect than iron on the colouring power.

5. A little copper is contained in ſome of the ores of cobalt, but does not much injure their quality.

An imperfect analyſis of the cobalt ores reſembling that of Tunaberg, and conſiſting chiefly of arſenic and cobalt is made in the dry way, by mixing the ore with charcoal,[a] or better with ſaw-duſt, and roaſting it to expel the *arſenic*, with the precautions deſcribed under that metal. The remaining oxyd, after thorough calcination, ſhould be mixed with about four times its weight of an equal mixture of carbonat of potaſh and tartar (or with any other ſaline reducing flux), and heated intenſely for about 15 minutes in a heat ſufficient to melt caſt iron. A button of reguline cobalt is found beneath the ſcoria, which laſt are always of an intenſe blue almoſt black, owing to the ſolution of part of the cobalt-oxyd. From 100 grains of the ore of Tunaberg Klaproth obtained in this way 44 grains of regulus of cobalt, but this would obviouſly be impure whenever the ore contained iron, or copper, or nickel, nor is it quite certain that every atom of the arſenic would be expelled.

The reducing flux employed by Beaumé is the following: mix one ounce of roaſted ore of cobalt with three ounces of black flux and half an ounce of potaſh, cover it when in the crucible with about one ounce of ſalt, and heat at firſt ſlowly, afterwards very briſkly for about a quarter of an hour.

For the mere purpoſes of analyſis the following laboured and accurate analyſis of the ſame by Taſſaert is much preferable,[b] the particulars of which may be given, as the whole is extremely inſtructive.

That the reader may better underſtand the proceſs it may be premiſed, that when reguline arſenic is boiled with a *little* nitric acid it is diſſolved and converted into white oxyd, all of which is depoſited by mere evaporation to a ſmall bulk of liquid: but when *much* nitric acid is uſed, the arſenic is more or leſs acidified, becomes thereby much more ſoluble in water, and then acting as an acid, it readily diſſolves cobalt, iron, &c. forming arſeniats of thoſe metals, which are decompoſable by the fixed alkalies. It may be alſo added, that oxyd of cobalt is ſoluble in ammonia, but oxyd of iron is not, and

[a] Klaproth.

[b] An. Chim. tom. 28.

that the nitrat of iron depoſits much of its iron by mere expoſure to air, but the nitrat of cobalt remains clear.

A. To eſtimate the quantity of arſenic ſeparately M. Taſſaert digeſted 100 parts of the cobalt ore with *dilute* nitric acid, and in ſome hours the whole was diſſolved, but by cooling depoſited a quantity of white cryſtalline grains. On evaporation more of them were depoſited, and when all had thus ſeparated they were collected and dried, and weighed 56 parts, all of which was ſublimed by heat except 3 parts, probably a mixture of arſenic and cobalt. Hence the oxyd of arſenic from this ore may be reckoned at about 53 parts, indicating 49 per cent. of metallic arſenic in the ore.

B. Three hundred parts of the ore were then digeſted with four times as much nitric acid, which made a roſe-coloured ſolution. By partial evaporation, adding water, and heating, a roſe-white precipitate (*a*) fell down, leaving a roſe-coloured ſolution. This ſolution boiled with an exceſs of potaſh gave an oxyd of cobalt at firſt roſe-coloured, then paſſing to green, and when dried in a red heat, black. It weighed 85 parts.

C. The 85 parts of the laſt experiment were then examined for iron. When re-diſſolved in nitro-muriatic acid, pure ammonia was added, which gave a black precipitate, which was all re-diſſolved by an exceſs of the alkali except a ſmall portion, which, again treated with nitro-muriatic acid and ammonia, was reduced to 4 parts, and appeared to be oxyd of iron.

D. The roſe precipitate of experiment B. which proved to be a mixed arſeniat of cobalt and iron, was decompoſed by cauſtic potaſh in exceſs, and gave a precipitate weighing 100 parts when dried.

E. The 100 parts of the laſt experiment were rediſſolved in nitric acid, the ſolution evaporated partly and then diluted with water. A precipitate of oxyd of iron weighing 27 parts then ſeparated, and a clear ſolution of cobalt was left.

F. The nitrat of cobalt of the laſt experiment was decompoſed by ammonia, and the precipitate rediſſolved by an exceſs of the alkali, except 15 parts of inſoluble oxyd of iron. The ſolution was added to the ammoniated cobalt of experiment C.

G. The inſoluble precipitates of oxyd of iron of C, E, and F were then mixed and examined. They ſtill gave a blue glaſs with borax, and therefore contained a certain portion of cobalt. Acetic acid was found a good method of ſeparating them. For this purpoſe they were rediſſolved in nitro-muriatic acid, precipitated by juſt ſufficient ammonia, and the precipitate whilſt ſtill wet was put into acetic acid. This diſſolved the whole at firſt, but on boiling and evaporating the ſolution nearly to dryneſs moſt of the iron ſeparated, and by rediſſolving in water and evaporating nearly to dryneſs ſucceſſively four times, nearly all the oxyd of iron was rendered inſoluble, whilſt the cobalt remained in the ſolution, and this acetited cobalt in proportion as it was freed from iron became more and more of a fine roſe colour. This laſt was then ſuperſaturated with ammonia, and the ſolution of ammoniated cobalt was added to the different portions of the ſame obtained in the former experiments. The whole was then boiled to expel the exceſs of ammonia, and by adding potaſh the whole of the pure oxyd was precipitated, which when well waſhed and dried, weighed 133 parts. This oxyd reduced in a crucible lined with charcoal, gave regulus of cobalt in its pureſt form, of the ſpecific gravity of 8.538, and to all appearance totally free from arſenic and iron.

H. Laſtly, to eſtimate the quantity of ſulphur, 100 parts of the ore were ſeparately boiled with 500 of nitric acid, and diluted with water to ſeparate all the oxyd of arſenic that would be depoſited ſpontaneouſly. All the ſulphur being now converted into ſulphuric acid by the action of the nitric acid, nitrat of barytes was added, and from the precipitated ſulphat of barytes the quantity of ſulphuric acid, and of courſe, of ſulphur, was eſtimated according to known proportions.

Some improvements may be ſuggeſted in this ingenious analyſis. To ſeparate the arſenic compleatly from the cobalt to which it adheres ſo obſtinately, Mr. Chenevix's method may be advantageouſly adopted of adding nitrat of lead to the ſolution of the ore containing the arſenic fully acidified and partly united to the cobalt. The nitrat of lead will engage all the arſenic acid, and decompoſe the arſeniat of cobalt. The arſeniat of lead, being inſoluble, remains at the bottom, the clear ſolution may then be decompoſed by carbonat of potaſh, which will ſeparate all the metallic contents, after which ammonia will diſſolve the cobalt, and alſo any nickel that may be preſent, leaving the iron and any exceſs of lead that may remain. The ammoniated ſolution of nickel and cobalt may be thus ſeparated, according to Mr. R. Phillips. [c] Let the ſolution be evaporated till the exceſs of ammonia is

[c] Phil. Mag. vol. 16. p. 313.

driven off (which is known by a paper dipped in turmeric liquor no longer turning brown) in this ſtate, if potaſh is added, and diluted with much water, the whole of the nickel is precipitated very ſpeedily, but the cobalt remains ſuſpended for a conſiderable time.

If copper be contained, after the arſeniat of lead is precipitated, as in the laſt proceſs, let the copper be ſeparated by a bar of iron before the nitric ſolution is decompoſed by alkalies.

In the large way cobalt and nickel may be conſiderably ſeparated by ſcorification with nitre, the oxyd firſt produced being chiefly cobalt. [d]

Cobalt was ſuppoſed by Brugnatelli [e] to be capable of acidification. This was found by Darracq [f] to be a miſtake, but ſome of the particulars will ſhew ſome further circumſtances relative to the union of arſenic acid and cobalt. If zaffre is digeſted in ammonia for ſome time, a red ſolution is formed, which when much evaporated depoſits a yellow oxyd. The clear ſolution, after dryneſs, is again ſoluble in water, but not the yellow oxyd. If zaffre is boiled in water, a ſolution is alſo obtained, which when evaporated depoſits a whitiſh oxyd, after which it cryſtallizes. The ſolution is ſenſibly acid, but is not a *cobaltic acid* as was ſuppoſed, but an arſeniat of cobalt with exceſs of acid. The oxyd in both caſes is not a pure oxyd of cobalt, but a mixture of cobalt with arſenic in ſome ſtate of oxygenation.

The pureſt poſſible regulus of cobalt obtainable by any yet known proceſs, is certainly that which is got from the ammoniated ſolution in the way above deſcribed, but as this is very expenſive, chemiſts have endeavoured with ſome ſucceſs to purify this metal by fuſion. Lampadius's proceſs [g] is the following. Project in a red-hot crucible a mixture of 4 ounces of ſmalt, 2 ounces of nitre, and half an ounce of charcoal. A ſtrong ſmell of arſenic is perceived in the proceſs, and a blackiſh grey maſs remains, which is to be again mixed with nitre and charcoal, and deflagrated as before: then throw into the crucible 2 ounces of black flux and heat it ſtrongly for an hour. This gives a tolerably pure regulus, weighing 6 drams. Powder it, and mix it with 1 dram of nitre and as much manganeſe, then put it in a luted double crucible, and heat it for an hour in a forge-furnace. The metal loſes by this operation all its iron, and is nearly pure, excepting a ſmall portion of arſenic, which may be further ſeparated if neceſſary.

Tromſdorf's proceſs is nearly ſimilar. [h] The zaffre or ſmalt is to be twice detonated with nitre, waſhed in hot water to carry off the arſenic now united with the alkali of the nitre, and the reſidue digeſted in nitric acid, which will only touch the cobalt, leaving the iron in the higheſt ſtate of oxidation. The purified oxyd of cobalt may then be reduced in the common way.

It may be obſerved on the ſubject of ſeparation of iron from cobalt (as this is of conſequence for manufacturing the fineſt poſſible colour from it) that when an alkali is added gradually to a mixed ſolution of the two metals, much of the iron precipitates before the cobalt falls, and this diſtinction is very obvious by the colour. Thus if carbonated potaſh be ſlowly added to nitrat of cobalt and iron, the firſt precipitate is a dull ochery ſlime, chiefly iron, after which the cobalt ſhews itſelf by a *violet* coloured precipitate, and thus a judicious addition of alkali (ſtopping when the violet colour is perceived) will alone purify the ſolution to a conſiderable degree.

Preparation of Zaffre, Smalt, and Azure.

All the zaffre and ſmalt of commerce is prepared in the large way in ſeveral parts of Germany, and particularly at Schneeburg in Miſnia, which affords a very lucrative trade to Saxony.

The cobalt ore is put on the hearth of a furnace like a baker's oven, [i] ſo conſtructed that the flame of wood is reverberated on all ſides over the ſurface, and ſoon heats it red-hot. A very denſe arſenical vapour then begins to be given out, which is conveyed through a very long horizontal wooden ſquare trough or chimney, ſometimes as much as a hundred fathoms in length, where the arſenic is chiefly condenſed, though Kunckel remarks that notwithſtanding this enormous length of chimney, ſome of the vapours ſtill eſcape through the further opening. The cobalt ore is calcined for ſome hours till it ſcarcely emits any more vapours, after which it is ground to powder, calcined a ſecond time, again ground and paſſed through a very fine ſieve. This powder is then mixed with two parts of powdered flints or quartz, moiſtened, and put in barrels, where it grows exceſſively hard. This forms the *zaffre* in the ſtate in which it is exported. The real reaſon of adding the flints appears to be for ſome purpoſes of concealment, the exportation of the ſimple calcined oxyd being forbidden under heavy penalties.

Smalt, ſometimes alſo called zaffre, and when

[d] Tromſdorf. [e] An. Chim. tom. 33. [f] An. Chim. tom. 41. [g] An. Chim. tom. 26. p. 89. [h] Ph. Jour. vol. ix.
[i] Kunckel in a note to Neri's Art de la Verrerie, p. 51.

finely powdered, *azure blue*, is a very deep blue glaſs, made of the calcined ore of cobalt and ſome vitrifiable ingredients, which is uſed as a colouring matter for a variety of purpoſes.[k] The proportion of the vitrifiable baſis to the cobalt depends on the eſtimated goodneſs of the latter and the reſult of ſmall trials. On an average, equal parts of the calcined cobalt ore, of potaſh, and of ground flints are taken. Theſe are firſt *fritted* and then made into glaſs, in pots ſimilar to thoſe of the glaſs-houſes, requiring from 8 to 12 hours of fuſion. When the blue glaſs is perfect, it is taken out with iron ladles and dropped into cold water to crack it in every direction and make it more eaſily reducible to powder, which is afterwards performed in a mill made of very hard ſtone incloſed in a wooden caſe. At the bottom of the glaſs-pots a quantity of regulus of biſmuth is always found, (the ores of biſmuth and cobalt being naturally mixed) and above it is a mixed alloy of arſenic, iron, and copper.

The grinding the blue glaſs is a work of labour and ſome difficulty. Several degrees of fineneſs are prepared by means of grinding and waſhing. Theſe are all known by the general term of *ſmalt*, or, when in very fine powder, *azure*. The term azure however is alſo applied to lapis lazuli blue, a totally different ſubſtance.

As a colouring matter ſmalt is very valuable, both on account of the fine intenſe blue which it produces, and for its comparative cheapneſs, and becauſe it is not altered by any heat. In this laſt reſpect it is ſuperior to lapis lazuli, the colour of which is entirely and permanently deſtroyed in a red-heat, but ſmalt will not mix with oil colours, and therefore can only be very partially uſed. Smalt is uſed when mixed with ſtarch to give a ſlight blue to linen, or rather to correct the tendency to yellow which linen acquires when worn.

Zaffre is prepared alſo in Bohemia, Wirtemberg, Sileſia, Lorrain, and ſome other parts of the Continent, but the Saxon is preferred, and yields to the proprietors an annual revenue of 200,000 crowns[l].

Cobalt, when rendered as pure as poſſible by the method above-deſcribed, has a ſteel-grey colour, not very reſplendent, when ſlowly cooled appears reticulated in its texture, is brittle, and fuſible at a heat about equal to that of caſt-iron. However carefully it has been freed from iron, it remains magnetic, and therefore there is reaſon to ſuppoſe that this is a property inherent in the metal itſelf.

Cobalt burns in oxymuriatic acid gas with a bright white flame, but in a common fire it only oxidates when heated ſtrongly in contact with air. In this caſe the oxyd is black. A hundred grains of reguline cobalt yield by this proceſs 118 grains of the black oxyd,[m] and hence 100 grains of the oxyd contain 84.75 of cobalt and 15.25 of oxygen When it contains arſenic the oxyd becomes ſomewhat reddiſh.

Cobalt or its oxyd is ſoluble in moſt acids.

The ſulphuric acid diſſolves cobalt with difficulty, but better its oxyds. A ſulphat of cobalt is formed by digeſting the black oxyd, or common zaffre, or the precipitate from nitrated cobalt by carbonated potaſh, with four times as much ſulphuric acid, ſomewhat diluted, or better, by diſtilling the acid from the cobalt to dryneſs and adding warm water to the reſidue. This ſolution evaporated ſlowly affords by cooling cryſtals of ſulphat of cobalt, which are of a fine red when the metal is pure, but greeniſh when it contains nickel.[n] Theſe cryſtals when ſlowly depoſited are often aluminiform. They require 24 parts of cold water for ſolution, but only 15 parts when heated to 145°.

Nitric acid diſſolves both cobalt and its oxyds copiouſly and with eaſe when gently heated and digeſted. The ſolution is red, or claret-coloured, or if holding iron, approaching to yellow. By evaporation it ſcarcely cryſtallizes, but leaves a ſaline deliqueſcent maſs. This when further heated parts with all its acid, and leaves a dark red or violet-coloured oxyd.

Muriatic acid acts with great difficulty on cobalt, and only by repeated evaporation to dryneſs and adding freſh acid. But the oxyds of this metal it diſſolves with much more eaſe. The ſolution is of a roſe-red, but when heated, and much concentrated, it aſſumes a beautiful blue green, more approaching to blue as the cobalt is more free from iron. It is neceſſary that the ſolution be concentrated to produce this effect, and the dry ſalt ſhews it ſtill more perfectly. This ſingular property of the muriat of cobalt was firſt uſed by Hellot in making a beautiful *Sympathetic Ink*. If characters be traced with this ſolution ſufficiently diluted on paper, they are ſcarcely viſible when cold, but when held before the fire they ſpeedily aſſume a very bright beautiful blue-green. On cooling they again become inviſible, and may at pleaſure be made again to appear and depart by alternately warming and cooling. The paper ſhould be no more heated than is neceſſary to produce the full effect. Any other ſolution of cobalt to

[k] Encycl. Arts & Metiers, art. Saffre. [l] Gerhard. [m] Klaproth. [n] Leonhardi.

which muriatic acid, or common ſalt, or muriat of ammonia, or muriatic acid in any form is added, will anſwer as well. Hence the ſympathetic ink is made at once by digeſting zaffre in nitro-muriatic acid with a moderate heat for ſome time, and diluting the ſolution with juſt ſo much water as will make writing appear of a full green when hot and inviſible when cold. As the nitric or muriatic acid is apt to corrode the paper, a ſtill better ink is made by adding a little common ſalt to ſaturated acetite of cobalt, and diluting ſufficiently with water.

The acetous acid only diſſolves the oxyd of this metal. The ſolution is of a claret red. The uſe of repeated digeſtions in this acid to free cobalt from iron has already been mentioned.

The action of the arſenic acid on cobalt has alſo been noticed in the analyſis of the cobalt ores. This ſolution is roſe-red, and by evaporation leaves a violet maſs, which again becomes red by digeſtion with hot water. This ſalt cryſtallizes without difficulty.

Moſt of the other acids diſſolve the oxyd of cobalt, forming metallic ſalts but little known and of trifling importance.

Muriated ammonia digeſted with oxyd of cobalt alſo diſſolves a portion and forms a green ſympathetic ink.

A triple ſalt of oxyd of cobalt, ammonia, and nitric acid is alſo formed by adding ammonia to nitrated cobalt. Slowly evaporated, this forms regular cryſtals, partly cubical, partly in the ſhape of inverted hollow pyramids, according to the obſervations of Thenard. [o]

This accurate chemiſt has alſo given ſome obſervations on the different ſtates of oxidation which cobalt is capable of aſſuming. When pure potaſh is added to a ſolution of cobalt, the precipitated oxyd appears at firſt blueiſh, but in the air it becomes olive. When waſhed with oxymuriatic acid it paſſes through ſucceſſive ſhades of brown red, and finally becomes black. This black oxyd therefore appears to be cobalt in the higheſt ſtate of oxygenation, and when put into muriatic acid it diſſolves therein with diſengagement of oxymuriatic gas, and the ſolution, if concentrated, becomes green, but in the air it ſoon turns to purple, and immediately roſe coloured if diluted with water. The brown and olive coloured oxyds alſo give oxymuriatic gas when diſſolved in common muriatic acid, but leſs copiouſly than the black oxyd. Alſo if the black oxyd is heated of a cherry red for half an hour it becomes blue, which then diſſolves in this acid without diſengaging any gas. The green colour of the muriatic ſolution appears entirely to depend upon its concentration, for, when diluted, whether hot or cold it is roſe-coloured. It appears therefore that the black oxyd is in its higheſt ſtate of oxygenation, and the blue in the leaſt, and that the olive and brown are in intermediate ſtates. With regard to the roſe and lilac colours ſo common to the *ſolutions* of cobalt, it is not certain that the *oxyds* when dry ever retain theſe ſhades, except when alloyed with arſenic or arſenic acid.

The fixed alkalies have ſcarcely any action on cobalt or its oxyds in the moiſt way, but ammonia diſſolves the oxyd with eaſe, and thus ſeparates it from iron and ſome other metals. The particulars of this ſolution have been mentioned in the analyſis. The ammoniated cobalt is decompoſed by potaſh, but ſlowly, whereas the ammoniated nickel which often exiſts in the ſame ſolution is precipitated thereby in a very ſhort time.

Tincture of galls added to the acid ſolutions of cobalt give a yelloviſh white precipitate when free from iron.

Pruſſiat of potaſh cauſes a green precipitate when the cobalt is pure.

Cobalt unites with great difficulty with ſulphur by artificial combination. Beaumé [p] projected ſulphur on cobalt in fuſion, but the metal did not appear to be ſenſibly altered by it, and all the ſulphur burnt off without difficulty. Monch [q] found however that cobalt could be ſufficiently ſulphuretted to furniſh a true cinnabar when afterwards heated with the white oxyd of mercury.

All the hydroſulphurets combine with this metal without difficulty, both in the liquid and the dry way. Hydroſulphuret of potaſh added to a ſolution of cobalt turns it black, and gives a black precipitate, which an exceſs of the ſulphuret rediſſolves.

Beaumé, on melting in a crucible 4 ounces of calcined cobalt ore, as much calcined gypſum, 6 ounces of ſalt of tartar, and 4 ounces of pitch, obtained a ready fuſion of the whole maſs in the ſulphuret of potaſh formed in the proceſs (the ſulphuric acid of the gypſum being deoxygenated by the pitch and then uniting to the alkali), which gave a metallic-looking maſs in large brilliant facets, beneath which was the earth of the gypſum and other ſcoria. This metallic ſulphuret was of a golden yellow colour and weighed 3 ounces. It ſoon tarniſhed in the air and deliqueſced entirely. Its ſolution in

[o] Thenard. An. Chim. tom. 42. [p] Chymic. Exper. [q] Leonhardi Worterbuch.

water was decompoſed by acids, which diſſolved the cobalt leaving the ſulphur. The ſulphur adheres ſo ſtrongly to the cobalt by the intermede of the alkali, that heat will not ſeparate them. This ſulphuret is much more fuſible than cobalt itſelf.

None of the alloys of cobalt deſerve particular notice. This metal does not unite, or only in very ſmall proportion, with biſmuth, ſilver and mercury. With gold, platina, copper, tin, iron, nickel, antimony and arſenic it unites eaſily and in various proportions. With lead, according to Gmelin, cobalt may be alloyed when wrapped up in ſheet lead and covered with charcoal.

All proportions of cobalt not exceeding equal weights with the lead make an uniform alloy, brittle and hard in proportion to the quantity of cobalt.

When lead or biſmuth are cupelled with cobalt, the latter is left behind in the form of a black oxyd.

The ſole uſe of cobalt in the arts is for the fine blue which any of its oxyds gives when mixed and melted with any vitrifiable matter. The extent of the colouring power is perhaps more than that of any other of the metallic oxyds, for one grain of the pure oxyd will give a very full blue to half an ounce, or 240 grains of glaſs. The oxyd melted *per ſe* gives ſo intenſe a blue as to appear perfectly black, except juſt at the thin edges of the ſharp fragments when broken. Manganeſe greatly impairs the clearneſs of the colour, giving a ſtrong admixture of muddy purple, but this effect is corrected by adding a little arſeniat of ſoda or other arſenical ſalt. (For further particulars on this ſubject ſee the article GLASSES *coloured.*)

Cobalt is alſo ſaid to be contained in ſmall quantity in ſome of the fine Chineſe metallic alloys, but its uſe is very doubtful, and the dearneſs of the metal would prevent it from being uſed to any extent for ſuch purpoſes in Europe.

It may be added that in moſt of the experiments on the alloys and the ſulphurets of this metal, it has been uſed in only its common ſtate of purity, that is to ſay, ſtill alloyed with arſenic and iron, and probably with nickel.

The affinities of cobalt are ſtated to be in the moiſt way as follows: the gallic, oxalic, muriatic, ſulphuric, tartareous, nitric, phoſphoric, fluoric, ſuccinic, citric, acetic, arſenic, boracic, pruſſic and carbonic acids, and ammonia.

COCCOLITE.[a] The colour of this mineral is graſs-green paſſing to olive or blackiſh green. It occurs in maſſes compoſed of ſmall granular diſtinct concretions like ſeeds or minute kernels (whence its name.) Theſe concretions are ſomewhat angular, and ſhew a tendency to cryſtallization. They have a conſiderable vitreous luſtre. The fracture of the grains is lamellar in two different directions, ſeemingly at right angles to each other: the fracture of the maſs is granular. It is tranſlucid; ſufficiently hard to ſcratch glaſs, and brittle. Sp.gr. 3.37.

Coccolite is very difficultly fuſible *per ſe* before the blowpipe. According to an analyſis by Vauquelin, it conſiſts of

50	Silex,
24	Lime,
10	Magneſia,
7	Oxyd of iron,
3	Ditto of manganeſe,
1.5	Alumine.
95.5	
4.5	loſs.
100.0	

This mineral has been lately diſcovered by Abildgaard, in veins at Arendahl in Norway, at Nerika in Sweden, and in the iron mines of Helleſta and Aſſebo in Sudermania. It has ſcarcely yet acquired a permanent ſtation in ſyſtems of mineralogy, and will probably be ranked as a variety of augite.

COCHINEAL. *Coccus Cacti Linn.*

The ſubſtance known in commerce by the name of cochineal, is in the form of hemiſpherical ſhrivelled grains, about an eighth of an inch long, of a deep reddiſh purple colour, and covered more or leſs with a white down; they are very light, and eaſily rubbed to powder between the fingers. The merchants diſtinguiſh at leaſt two kinds, called *grana fina* and *grana ſylveſtra*; of theſe the latter is not more than half the ſize of the former, and covered with a much longer down; on which account it always bears a much lower price in the market.

Cochineal was firſt introduced into Europe from Mexico about the year 1523, and was for ſome time ſuppoſed to be the berry or ſeed of a vegetable. It was at length however aſcertained that theſe grains were the females of a particular ſpecies of inſect, called by naturaliſts Coccus cacti, and of the ſame genus as the Kermes (*Coccus Ilicis Linn.*)

The cochineal inſect is a native of Mexico, and was in common uſe among the inhabitants as a dying-drug when the Spaniards firſt came

[a] Hauy, Brochant.

into the country; ſince that period its uſe has become more and more general, not only in Europe, but in various parts of Aſia, and as almoſt the whole of this valuable commodity is ſtill raiſed in Mexico, Peru, and the adjoining Spaniſh ſettlements, it becomes every year an object of more ſedulous cultivation than before.

The wild cochineal (grana ſylveſtra) feeds upon moſt of the ſpecies of cacti that are natives of Mexico, requires no particular care or attendance, and may be gathered ſix times in the year, there being ſo many generations of this inſect in a twelvemonth: the time of collecting the cochineal is juſt before the female produces its young, as the animal periſhes immediately afterwards. The cultivated cochineal (grana fina) is ſuppoſed to have originated from the wild kind: but this opinion appears very doubtful. If it be granted that the ſuperior ſize of the former, and its want of thoſe long white hairs or down which cover the latter may be the effect of domeſtication, there ſtill remain two other diſtinctive characters which appear to be original; theſe are, its feeding only upon one ſpecies of cactus, the cochenillifer, or nopal, and its producing only three broods or generations in the year. The management of the cochineal inſect is ſimple, but requires inceſſant attention. At the third annual gathering of cochineal a certain number of females are left adhering to branches of the nopal, which are then broken off and kept carefully under cover during the rainy ſeaſon; when this is over, the ſtock of cochineal thus preſerved by each cultivator is diſtributed over the whole plantation of nopals, where they ſoon multiply with great rapidity. In the ſpace of two months the firſt crop is gathered by detaching the inſects with a blunt knife, after which they are put into bags and dipped in hot water to kill them, and finally dried in the ſun, by which they loſe about two-thirds of their weight. The proportion of colouring matter contained in equal portions of the cultivated cochineal, the wild cochineal of Mexico and an inferior kind from St. Domingo, is as eighteen, eleven, and eight.[a] The average quantity of fine cochineal annually conſumed in Europe amounts, according to Dr. Bancroft, to 600,000 lbs. When thoroughly dry it experiences no change from long keeping in cloſe packages: Hellot affirms that he uſed ſome which was 130 years old, and found it as good as if it had been quite freſh.

The colouring matter of cochineal may be extracted either by water or alcohol. The alcoholic ſolution is of a deep crimſon colour, and on evaporation leaves a tranſparent reſiduum of a deep red, which has the appearance of a reſin. The aqueous ſolution or decoction of cochineal is of a violet crimſon colour, and this if evaporated ſlowly to the conſiſtence of an extract, and then digeſted in alcohol, communicates to this menſtruum a colour ſimilar to the preceding ſpirituous ſolution, a reſiduum of the colour of wine lees being left behind.

The aqueous decoction of cochineal if mixed with a little ſulphuric acid aſſumes a red colour, inclining to yellowiſh, and a ſmall quantity of a fine red precipitate is thrown down. Muriatic acid produces nearly the ſame change of colour, but occaſions no precipitate. A ſolution of tartar changes the cochineal decoction to a yellowiſh red, and a ſmall quantity of a pale-red precipitate is ſlowly depoſited: the ſupernatant liquor is yellow, but on the addition of a little alkali it becomes purple, the precipitate being at the ſame time rediſſolved. Alum brightens the colour of the infuſion and gives it a redder hue; a crimſon precipitate is depoſited, and the ſupernatant liquor retains a ſimilar tinge. A mixture of alum and tartar produces a brighter and more lively colour, inclining to yellow: a precipitate is thrown down, but much paler and leſs in quantity than where alum alone is uſed. Nitrio-muriat of tin throws down a copious crimſon ſediment, not a particle of colouring matter remaining in the liquor. Sulphat of iron forms a browniſh-violet precipitate, and the ſupernatant liquor is of a dilute yellowiſh-brown. Sulphat of zinc forms a deep violet, and acetite of lead a purple-violet precipitate, the liquor in both caſes being perfectly colourleſs. Sulphat of copper changes the colour of the decoction to violet, and a ſmall ſediment of the ſame colour very ſlowly ſubſides.

Cochineal is uſed either as the baſis of that fine pigment called carmine and lake-red, or as a dying drug to tinge wool and ſilk, either ſcarlet or crimſon, or the finer kinds of violet.

The preparation of carmine and lake-red is ſo valuable a proceſs, and one ſo eaſily kept ſecret, and its perfection depends ſo much on nicety of manipulation, that none of the publiſhed methods in all probability will afford it of the very beſt quality. The following is perhaps the beſt of thoſe which have yet been made public, and if carefully purſued will yield a pigment greatly ſuperior to the carmine that is generally met with.[b]

[a] Berthollet on Dying, II. p. 169.

[b] Alyon Cours de Chimie, II. p. 174.

Into a 14 gallon boiler of well tinned copper, put ten gallons of diſtilled or very clear river or rain water (ſpring-water will not anſwer the purpoſe). When the water boils ſprinkle in by degrees a pound of fine cochineal previouſly ground in a clean ſtone mortar to a moderately fine powder: keep up a moderate ebullition for about half an hour, and then add three ounces and half of cryſtallized carbonat of ſoda: in a minute or two afterwards draw the fire, and then add to the liquor an ounce and a half of Roman alum very finely pulverized; ſtir the maſs with a clean ſtick till the alum is diſſolved, then leave it to ſettle for 25 minutes: draw off the clear liquor with a glaſs ſyphon, and ſeparate the ſediment from the reſidue by ſtraining it through a cloſe linen cloth. Replace the clear liquor in the boiler and ſtir in the whites of two eggs previouſly well beaten with a quart of warm water; then light the fire again and heat the liquor till it begins to boil, at which time the albumen of the eggs will coagulate and combine with the earth of the alum and the fineſt part of the colouring matter: this ſediment is the carmine, and being ſeparated by filtration, and well waſhed on the filter with diſtilled water, is to be ſpread very thin on an earthen plate and ſlowly dried in a ſtove: after which it is ready for uſe. The fineſt part of the colouring matter of the cochineal being thus ſeparated, the reſidue may be employed in the preparation of red lake in the following manner. Add two pounds of pearlaſh to the red liquor from which the carmine was precipitated, and return it into the boiler together with the dregs of the cochineal, and boil the whole gently for about half an hour; then draw the fire, and after the ſediment has ſubſided drain off all the clear liquor into clean wooden or earthenware veſſels (the latter however are the beſt, as the alkaline ſolution is apt to diſſolve a little extractive matter from the wood). Then pour upon the ſediment a ſecond alkaline ley prepared by diſſolving a pound of pearlaſh in two gallons of water, and boil this alſo upon the dregs for half an hour, by which proceſs the whole of the colouring matter will be exhauſted. Separate by filtration the liquor from the dregs, and return both the alkaline ſolutions into the copper. When this bath is as hot as the hand can bear, add by degrees three pounds of finely pulverized Roman alum, obſerving not to add a ſecond portion till the effervescence from the firſt has entirely ſubſided. When the whole of the alum has been put in, raiſe the fire till the liquor ſimmers, and continue it at this temperature for about five minutes, at which time if a little is taken out and put into a wine glaſs, it will be found to conſiſt of a coloured ſediment diffuſed through a clear liquor. After ſtanding quiet a while the greater part of the clear ſupernatant liquor may be poured off, and the reſidue being placed on the filter, will there depoſit the coloured lake, which after being accurately waſhed with clean rain water, may be covered with a cloth and allowed to remain for a few days till it is half dry: it is now to be ſeparated from the filter, to be made up in ſmall lumps and placed in a ſtove to dry. By this management a pound of good Mexican cochineal will afford one ounce and a half of carmine, and about a pound and a quarter of red lake.

If the colour is required to incline ſomewhat towards ſcarlet, this may be effected by grinding along with the cochineal from a quarter to half an ounce of the beſt annotta.

For the uſe of cochineal in DYING, ſee that article.

COELESTINE. *Celeſtin*, Warner. *Strontiane Sulphatée*, Hauy.

The native ſulphat of ſtrontian, called cœleſtine, from the bluiſh tint which it generally aſſumes, is divided into three varieties, the fibrous, foliated, and compact.

1. Fibrous cœleſtine. *Faſriger celeſtin.*

Its colour is between indigo-blue and bluiſh-grey, paſſing ſometimes into milk-white, by keeping it becomes white or colourleſs. It occurs in maſs, in plates and cryſtallized. Its longitudinal fracture preſents a ſhining luſtre, its croſs fracture is gliſtening and pearly. Its longitudinal fracture is curved-fibrous, approaching to foliated; its croſs fracture is ſplintery. It is tranſlucent; ſomewhat ſofter than fluor; eaſily frangible: ſp. gr. = 3.83.

According to the analyſis of Klaproth[a] it contains

58	Strontian
42	Sulphuric acid,
——	with a trace of iron
100	

It occurs in ferruginous marl in the vicinity of Briſtol, and at Frankſtown in Pennſylvania.

2. Foliated Cœleſtine. *Blattriger celeſtin.*

Its colour is milk-white, paſſing into blue: it occurs in maſs, or cryſtallized.

1. In ſtrait priſms, with rhomboidal baſes (which is its primitive form) the angles of which are 104°—48′ and 75°—12′.

2. In cuneiform octahedrons.

[a] Analyt. Eſſ. I. p. 394.

3. In ſhort hexahedral priſms.

Its luſtre is gliſtening or ſhining: its fracture is imperfectly foliated: it is ſemi-tranſparent, rarely tranſparent. In hardneſs and frangibility it reſembles the preceding variety. Sp. gr.=3.5.

It has been analyſed by Vauquelin, and found to contain

54	Strontian
46	Sulphuric acid
100	

It occurs in the neighbourhood of Briſtol in looſe nodules, and very finely cryſtallized in Sicily.

3. Compact cœleſtine. *Dichte celeſtin.*

Its colour is bluiſh or yellowiſh-grey. It occurs in maſs and in flattened ſpheroidal and kidney-ſhaped pieces. Its fracture is fine-ſplintery, paſſing into foliated. It is opake, and ſometimes tranſlucent on the edges. It is ſoft and eaſily frangible. Sp. gr.=3.59. It has been analyſed by Vauquelin, and conſiſts of

91.42	Sulphat of Strontian
8.33	Carbonat of lime
0.25	Oxyd of iron
100.00	

It occurs imbedded in clay in the gypſum quarries of Mont Martre, near Paris.

COHOBATION is the repeated expoſure of one ſubſtance to the chemical action of another ſubſtance, either by returning the latter when driven off by diſtillation, or by ſupplying a freſh quantity after the action of the firſt has been exhauſted.

COLCOTHAR is the red oxyd of iron which remains after the diſtillation of aqua-fortis in the large way, when the ſulphat of iron is the ſalt uſed for the decompoſition of the nitre. Colcothar is iron in its higheſt ſtate of oxygenation, and when waſhed, and properly ſifted and levigated, it is much uſed in poliſhing iron and other hard bodies.

COLD. The opinions relative to the nature of cold are mentioned under the article *Caloric*. For the different means of producing artificial cold, ſee alſo FREEZING.

COLOPHONY is a hard black reſin, artificially prepared from *Turpentine*, (which ſee).

COLOURING *Matter*. For the nature of colouring matter ſee the article *Dyeing*. Some of the moſt important of theſe, ſuch as *cochineal*, *indigo*, *madder*, &c. have been analyzed by chemiſts, and are ſeparately noticed.

COLUMBIUM is the name given by the diſcoverer, Mr. Hatchett,[a] to a ſubſtance hitherto undeſcribed, and apparently metallic, found in a certain ſpecimen in the Britiſh Muſeum, ſent from ſome part of North America, probably Maſſachuſets.

The ſpecimen is a dark browniſh grey ore, imperfectly lamellated in its longitudinal fracture, of a vitreous luſtre, moderately hard and brittle, not magnetical, its ſpecific gravity is 5.918.

The following analyſis ſhews it to conſiſt of iron and a peculiar unknown ſubſtance in the proportions of about one of the former to 3 of the latter.

The ore was ſucceſſively boiled with muriatic, nitric, and ſulphuric acids. Of theſe, the ſulphuric acted the moſt powerfully, and the muriatic the next, but neither of them produced a full ſolution of the ore but appeared only to act on a portion of the iron which it contained.

It was therefore neceſſary to purſue the admirable method of previouſly breaking the coheſion of its parts by fuſion with alkali, ſo advantageouſly employed by Klaproth and other modern analyſts in the examination of refractory minerals.

The ore was accordingly powdered and heated in a ſilver crucible with five times its weight of carbonat of potaſh. When the alkali began to melt, an effervеſcence took place, owing to the union of the ore with the potaſh, after which the whole ſubſided into a maſs, greyiſh-brown when cold. Boiling water diſſolved a portion, making a clear alkaline ſolution. The inſoluble reſidue was digeſted in muriatic acid, which diſſolved another portion, but ſtill leaving a reſidue. This laſt was again fuſed with carbonat of potaſh, and gave as before a portion ſoluble in water, another on muriatic acid, and a reſidue. This laſt entirely diſappeared by continuing the ſame plan, and thus the whole was reſolved into ſeveral ſimilar portions of an alkaline ſolution, and an equal number of muriatic ſolutions. The alkaline ſolutions ſuperſaturated with nitric acid gave a white flocculent precipitate, not ſoluble in an exceſs of the ſame acid. The muriatic ſolutions were mixed, ſaturated with ammonia, and gave an ochery precipitate, the iron of which was diſſolved in nitric acid, and the remainder was now white, and reſembled the precipitate from the alkaline ſolutions.

The nitrat of iron gave by ammonia 42 grains of oxyd of this metal (from 200 of the

[a] Phil. Trans. for 1802.

ore) and the white flocculent matter weighed about 155 grains. This laſt being obviouſly a peculiar ſubſtance was examined ſeparately, and was found to have the following properties, which (collectively taken) diſtinguiſh it from any other known ſubſtance, and at preſent may be conſidered as pure *columbium*, or rather as the ſuppoſed oxyd (but as yet irreducible) of a metal to which the name of columbium has been given.

This ſubſtance is white and not very heavy. It has no taſte, and is ſcarcely ſoluble in water, but, laid on litmus-paper, it turns it red, and hence it may be inferred to be ſlightly acid.

Under the blow-pipe it is not fuſible *per ſe*, nor with borax, but readily, and with effervescence with the carbonats of ſoda and potaſh. Phoſphat of ammonia, or phoſphoric acid diſſolve it alſo in this way, and produce a purpliſh blue globule.

Nitric acid has no action whatever upon it.

Boiling ſulphuric acid is the beſt of the acid menſtrua for this ſubſtance, and diſſolves it eaſily, but the greater part of the ſolution is decompoſed by dilution with water, and a heavy inſoluble ſulphat of columbium ſubſides as a white powder. It requires ſome minutes for this effect to take place.

Pruſſiat of potaſh, added to the ſulphuric ſolution produces immediately a copious beautiful olive precipitate.

Tincture of galls gives an orange-coloured precipitate.

All the alkalies decompoſe the ſulphuric ſolution, but when in exceſs do not rediſſolve the precipitate unleſs heated.

Boiling muriatic acid diſſolves the white precipitate from the ſolution of columbium, in potaſh, by an acid, if taken wet and recently ſeparated.

A muriat of columbium is thus produced which is not cryſtallizable. A piece of zinc immerſed in this ſolution gives a white flocculent precipitate, but nothing in a metallic ſtate.

The fixed alkalies diſſolve columbium in the moiſt way as well as by fuſion. The ſolution in potaſh, when evaporated, gives a white glittering ſcaly ſalt reſembling boracic acid in appearance, and of an acrid alkaline flavour.

Columbium is inferred to be of a metallic nature, by forming coloured precipitates with pruſſiat of potaſh and galls, by being ſeparable from its ſolution by zinc, and by colouring phoſphoric acid melted with it, but the attempts to reduce it to the reguline ſtate by fuſion with charcoal, have not ſucceeded.

From its reddening litmus it appears to be in the ſtate of an acid.

COMBUSTION is the rapid decompoſition of any body attended with the production of LIGHT and CALORIC. In all the great proceſſes of combuſtion that are conſtantly going on, the preſence of OXYGEN in one form or other is eſſentially requiſite, which appears to be the great agent of this decompoſition; as the *products* of combuſtion conſiſt principally of the combuſtible materials united with the oxygen employed. As the evolution of light and heat are included in the popular idea of combuſtion, it ſeems proper to retain theſe phenomena in the definition, and thereby to diſtinguiſh it from *oxygenation* in which they are wanting. It muſt be acknowledged however that the products of combuſtion, in many inſtances, do not ſenſibly differ from thoſe of ſimple oxygenation, and hence Lavoiſier was led to uſe the term *ſlow combuſtion*, to expreſs oxygenation without the ſenſible evolution of light and heat. This has led to ſome probable opinions on the nature of oxygen, which will be mentioned under that article.

CONGELATION. See FREEZING.

COPAL. This ſingular kind of reſin is brought principally from South America, and partly from the Eaſt Indies, and is a natural exſudation from a large tree which hardens on expoſure to air. Copal is one of the hardeſt of the reſins, and eaſily reducible to a very fine powder. It is beautifully tranſparent, and chiefly of a light-lemon colour, ſometimes inclining to orange, but the colour of the fineſt ſort is ſo faint that when ſpread thinly over any ſurface as a varniſh it is not perceptible, and only gives a fine hard ſmooth tranſparent glazing. It is this union of hardneſs with colourleſs tranſparency that makes copal ſo eminently valuable as a varniſh for pictures, white-wood works, and a variety of other purpoſes.

The common reſins are characterized by being inſoluble in water, ſoluble in alcohol, eſſential oils, and ether, and highly combuſtible. Copal agrees with the reſins in combuſtibility and all external characters, but it cannot be diſſolved in the above menſtrua without particular pains, and requires them to be in a ſtate of extreme purity. In theſe qualities therefore it appears to hold an intermediate ſtate between the true reſins and amber, reſembling the former by being ſoluble in oily ſubſtances which do not touch amber, and the latter by greatly reſiſting the action of alcohol.

As it is a process of some nicety to produce a true solution of copal fit for the purpose of a varnish without impairing the colour, some of the directions laid down by practical artists may here be inserted. The following is given by Mr. Sheldrake[a] as the result of long practical observation. Reduce two ounces of copal to *coarse* powder (not fine) put it into a glass vessel and pour thereon a mixture of one pint of the best oil of turpentine with one-eighth of spirit of sal ammoniac, previously well shaken, cork the glass, leaving a small hole through the cork, to allow the escape of the spirituous vapour, and speedily heat it to that point at which the bubbles may be counted as they rise to the surface. Continue this heat, neither increasing nor lessening it, till the solution is compleat, or till no more will dissolve. The mixture becomes somewhat milky at first, then the upper surface clears, whilst the copal swells, softens, becomes opake, and gradually diffuses itself through the spirit, dissolving therein. It should seem that this process requires much nicety of management in regulating the heat, for if ever this is increased the bits of copal resume their transparency,[b] no longer coalesce, and remain afterwards perfectly insoluble. It is also of the utmost consequence that the oil of turpentine be of the best sort, and very highly rectified. The vessel should not be opened till quite cold, otherwise the sudden escape of the vapour will carry out with it a great part of the solution. This varnish is of a rich deep colour when viewed in the bottle, but gives no sensible colour when laid on.

Copal may also be united with oil of turpentine very conveniently by the intermede of other essential oils, particularly oil of spike, or oil of lavender. The following process is given by M. Tingry.[c] Put 2 ounces of essential oil of lavender into a glass matrass heated by a lamp, or over a moderate fire, add thereto when very warm one ounce of copal grossly powdered, and at different times stirring it with a stick of white wood; when the copal is dissolved add 6 ounces of boiling oil of turpentine, dividing it into three doses at as many different times, and keep stirring till the whole is uniformly mixed. This varnish will be of a fine gold colour, very durable and brilliant.

Ether is also a good solvent for copal.[d] Reduce half an ounce of copal to fine powder, and put it by small portions into a flask containing 2 ounces of cold sulphuric ether of the purest kind. Shake it well, and in some hours the solution will be complete. If the liquor is not perfectly clear add more ether.

The remarkable effect of camphor in promoting the solution of the resins has been mentioned under that article. With none is this property shewn more strikingly than with copal. When the two are separately powdered and then mixed, the copal absorbs the camphor, swells, and softens into one coherent mass which will remain for six months of the same pasty consistence, though kept in a warm dry room.[e] By the intermede of camphor, copal may be completely dissolved in alcohol. Dissolve half an ounce of camphor in a pint of alcohol, put it into a glass vessel over a moderate fire, and add four ounces of copal in small pieces, continue the heat that the bubbles may be counted, till the solution is complete. A part of the copal will separate when the liquor is cold, but enough will be retained to give a fine colourless varnish.

Camphor also assists the solution of copal in oil of turpentine according to the following process, also given by Mr. Sheldrake. Dissolve half an ounce of camphor in a quart of oil of turpentine, take a piece of copal the size of a walnut, bruize it into coarse powder, add it to the camphorated oil of turpentine, and *bring it to boil as soon as possible*, then keep it gently boiling for an hour, and enough of the copal will be dissolved to form a good varnish. The vessel (glass or tin) in which the solution is made should be closely corked, leaving only a very small hole for the escape of the vapour to prevent the vessel from bursting, an accident which (from the extreme combustibility of the ingredients) might be attended with very serious consequences.

The above process should be followed precisely, for if the camphor is not added first, or if the copal is in fine powder, these two substances at once unite, forming a mass like birdlime at the bottom of the vessel, and the solution will not go on.

Copal may also be dissolved according to Demmenie,[f] by being suspended in a glass receiver over alcohol or oil of turpentine, and applying heat to make the liquor boil. The vapours arising from it liquify the copal which falls in drops into the boiling fluid, and immediatley dissolves.

For a copal varnish which is to unite the qualities of transparency and durability, to a

[a] Transact. of the Society of Arts. [b] Phil. Jour. vol. 9. 8vo. [c] The Painter's and Varnisher's Guide, 1804.
[d] Tingry. [e] Sheldrake. [f] Phil. Jour. vol. 2. p. 142.

certain degree of pliability, M. Tingry gives the following receipt. Take of powdered copal 2 ounces; of oil of lavender 6 ounces; of camphor one drahm; and of oil of turpentine as much as is wanted to give the requiſite conſiſtence. The camphor and oil of lavender are to be ſeparately liquefied, then the copal diſſolved therein, and laſtly the oil of turpentine added boiling-hot and incorporated by ſtirring. This the author conſiders as fit for the ingenious proceſs of varniſhing wire gauze, in the Chineſe manner, for lanthorns, to be uſed where a lighter and leſs brittle material than glaſs is wanted.

In the compoſition of the drying-oil varniſhes with amber or copal, it is well known that a greater heat is required than in the former ſpirit varniſhes, as it muſt be ſufficient to liquify the reſin before it will unite with the oil. Both amber and copal have the diſadvantage of becoming brown and coloured by a melting heat, applied in the common way, and hence it is a great object to find ſome method of melting theſe reſins without impairing that tranſpareney for which they are ſo much valued.

M. Tingry finds this object to be conſiderably attained by incloſing the copal in a wire-net hanging in the centre of a ſmall furnace of peculiar conſtruction, and with a very moderate and well regulated fire, whence the copal, as ſoon as liquefied, falls down through a conducting tube, and may be thus dropped in a liquid ſtate into hot drying oil ſet below to receive it. They immediately unite, and when afterwards tempered with ſufficient hot oil of turpentine, a fine drying oil varniſh is formed, which has but little colour and retains its tranſpareney.

If the melted copal is received into water a ſmall quantity of oil is ſeparated, which is found floating at the top, and the copal appears to be rendered thereby ſomewhat more ſoluble in different menſtrua.

As copal is expenſive it is ſometimes adulterated with gum anime when very tranſparent. The latter is diſtinguiſhed by being more friable, and for giving a ſweet odour when rubbed. Copal will unite with other reſins in compound varniſhes, and many of the liquors commonly ſold for copal varniſh, contain only a ſmall portion of copal, the other reſinous baſis being compoſed of maſtich, ſandrach, and others of the moſt colourleſs reſins.

COPPER. *Cuprum*, *Lat.* *Kupfer*, Germ. *Cuivre*, Fr.

Copper is a malleable and ductile metal of a pale-red colour with a tinge of yellow. It is ſoluble with effervescence in nitrous acid, to which it gives a ſky-blue colour: on the addition of liquid ammonia a green precipitate is thrown down, which is re-ſoluble in an exceſs of ammonia, forming a very rich purpliſh-blue fluid, and from this, if ſlightly ſuperſaturated with muriatic acid, the copper is again precipitable in its metallic form by a bar of clean iron.

The ores of this metal are very numerous,[a] and may with moſt convenience be arranged under the eight following families.

I. Family. NATIVE COPPER.

Sp. I. Native Copper. *Gediegen Kupfer*. *Cuivre natif*.

Its colour is a clear copper-red, often tarniſhed externally yellowiſh, blackiſh or greeniſh. It occurs in maſs, diſſeminated, in leaves, in rolled pieces, in grains, capillary, filiform, moſs-like, dendritical and cryſtallized.

1. In cubes, either entire or truncated at the edges and angles.

2. In octahedrons, either regular or combined with the cube.

3. In pyramidal dodecahedrons formed of two ſix-ſided pyramids, with a ſhort ſix-ſided priſm interpoſed.

The cryſtals are ſmall or very ſmall, ſeldom ſingle and moſt commonly implanted in each other, forming dendritical or cluſtered maſſes. Its external luſtre is caſual, its internal is gliſtening and metallic. Its fracture is hackly: when cut or rubbed it has a ſhining metallic luſtre. It is not very hard, is malleable and flexible without being elaſtic, and difficultly frangible. Sp. gr. of the Hungarian 7.72, of the Siberian 8.58.

It is fuſible before the blowpipe, and appears to be pure copper.

It occurs in veins and beds in quartz and granite, in ſlate, porphyry, ſerpentine, hornſtone and limeſtone, accompanied by various other ores of copper, particularly the red oxyd, malachite and copper pyrites, with galena, horn-ſilver, native ſilver, calcareous ſpar, heavy-ſpar and fluor.

It is very generally, though not often very abundantly diffuſed. The fineſt ſpecimens come from the Tourinſki mines on the eaſtern ſide of the Uralian mountains, from Herrngrund in Hungary, from Saxony, the Hartz, Fahlun in Sweden, and Cornwall. It is ſaid to be remarkably abundant in Japan and Brazil, and to contain a conſiderable proportion of gold. It is alſo procured in quantity from the Copper-mine river within the Arctic circle in America.

[a] Kirwan, Hauy, Brochant, Jameſon, Emmerling, Bournon in Phil. Tranſ.

II. Family. Oxyd of Copper.

Sp. II. Ruby Copper. *Florid red Copper ore*, Kirw. *Roth Kupfererz*, Werner. *Cuivre oxydé rouge*, Hauy.

Of this ſpecies there are the following varieties.

Var. 1. Lamellar R. C. *Blattriges R. K.* Werner.

Its colour is dark cochineal-red, inclining ſometimes to lead-grey; when cryſtallized it is often of a full carmine-red. It occurs in maſs, diſſeminated and cryſtallized.

1. In cubes.

2. In aluminiform octahedrons, either perfect or truncated on the angles or on the edges and angles.

The cryſtals are ſmall and very ſmall, and are often aggregated together by their ſides; their ſurfaces are ſmooth and ſhining. The internal luſtre of this mineral is more or leſs ſhining, and is intermediate between metallic and that of the diamond. Its fracture is imperfectly foliated paſſing into granular uneven. It occurs ſometimes in granular diſtinct concretions paſſing into the compact variety. When in maſs it is uſually opake or at moſt tranſlucent on the edges; the cryſtals are tranſparent, verging into tranſlucent. It gives a browniſh brick-red ſtreak, is moderately hard, brittle and eaſily frangible. Sp. gr. 3.95.

By expoſure to the blowpipe on charcoal it is eaſily reducible to a metallic bead without emitting either odour or ſmoak. It diſſolves in the nitrous and muriatic acids, in the former with and in the latter without effervescence. According to the analyſis of Mr. Chenevix, it conſiſts of

88.5 copper,
11.5 oxygen.

100.0

It is met with chiefly in veins, and appears to be peculiar to primitive mountains: the ſubſtances with which it is accompanied are native copper, malachite, and brown iron ochre; ſometimes mountain green, copper pyrites and other ores of this metal, alſo quartz, calcareous and heavy ſpars.

It is found in Cornwall, in Hungary, Saxony, the Hartz, Siberia, Peru and Chili.

Var. 2. Capillary R. C. *Haarformiges R. K.* Werner.

This variety differs from the preceding in being of a ſomewhat lighter colour, ſuperior luſtre, and being compoſed of ſmall capillary cryſtals and thin flakes.

Var. 3. Compact R.C. *Dichtes R.K.* Wer.

It occurs in maſs and diſſeminated but never cryſtallized: its internal luſtre is glimmering, ſemi-metallic. Its fracture is even, and it is opake. In other reſpects it agrees with Var. 1.

Sp. III. Tile-red Copper. *Brick-red Copper*, Kirw. *Ziegelerz*, Werner.

This ſpecies is found in two ſtates, indurated and earthy.

Var. 1. Indurated T. C. *Feſtes Z.* Werner.

Its colour is intermediate between hyacinth and browniſh-red, and paſſes on the one hand into lead and dark ſteel-grey, and on the other into blackiſh or reddiſh brown. It occurs maſſive and diſſeminated. The reddiſh kind has a glimmering luſtre and flat conchoidal fracture, the browner kind has a ſomewhat reſinous luſtre and ſmall conchoidal fracture. It acquires a luſtre by friction, is moderately hard and brittle.

When expoſed to the blowpipe it becomes black and is infuſible without addition. Borax is tinged by it of a dirty green. It appears to be an intimate mixture of compact ruby copper with brown iron ochre, and its produce of copper varies from ten to fifty *per cent.*

It occurs in veins with ruby copper, malachite, copper pyrites and iron ochre. It paſſes into brown iron ſtone.

Var. 2. Earthy T. C. *Erdiges Z.* Werner.

Its colour is hyacinth-red, paſſing into reddiſh or yellowiſh-brown. Its texture is between friable and ſolid. It occurs in maſs, diſſeminated, and incruſting copper pyrites. It is without luſtre, has an earthy fracture and ſlightly ſoils the fingers. In its other characters it agrees with the preceding variety.

III. Family. Sulphuret of Copper.

Sp. IV. Vitreous Copper. *Kupferglas*, Wer. *Cuivre vitreux*, Broch. *Cuivre ſulfuré*, Hauy.

Its colour is dark lead-grey paſſing into blackiſh grey, it often preſents a ſuperficial ſteel-coloured tarniſh. It occurs in maſs, diſſeminated, or cryſtallized.

1. In cubes.

2. In octahedrons.

3. In hexahedral prisms, either regular or terminated by trihedral ſummits placed on three of the lateral ſides.

The cryſtals are ſmall and very ſmall. Externally they are ſhining; internally they exhibit a gliſtening metallic luſtre. The fracture is fine grained uneven, paſſing into conchoidal and thence into even. It gives a ſhining ſtreak, is blackiſh when pulverized; commonly breaks ſhort under the knife, and is eaſily frangible. Sp. gr. 4.1 to 5.4.

It effervefces with nitrous acid, and when expofed to the blowpipe it gives a metallic button generally of a fteel grey colour and attractable by the magnet.

When pure it appears to be a fimple fulphuret of copper, and is found occafionally in this ftate in Cornwall, when it confifts, according to Chenevix, of

81	Copper,
19	Sulphur.
100	

It is generally however mixed with iron in the proportion of from 3 to 6 *per cent.* Klaproth analyfed a fpecimen from Siberia, which contained

78.5	Copper,
18.5	Sulphur,
2.25	Iron,
0.75	Silex.
100.00	

It occurs in veins and beds in primitive and floetz mountains, accompanied by copper pyrites and other ores of this metal. It is not very abundant, but is found in various places, efpecially Cornwall, Hungary, Saxony, Norway and Siberia.

Sp. V. Purple Copper. *Buntkupfererz*, Wer. *Cuivre pyriteux hepatique*, Hauy.

Its colour is intermediate between copper-red and tombac-brown; on expofure to the air it becomes firft reddifh, then violet azure and fky-blue, and laftly green; its general tinge however is blue, and the green only occurs in fpots. It is found in maffs or difleminated, or fuperficial, or, according to fome writers, cryftallized in octohedrons. Internally it is fhining, with a metallic luftre. Its fracture is fmall and imperfect conchoidal, paffing into fine-grained uneven. It takes a polifh by friction, and when pulverized is of a reddifh colour. It is fo foft as in fome degree to yield to the nail; and is eafily frangible. Sp. gr. about 5.

It effervefces with nitrous acid, though by no means fo ftrongly as the preceding fpecies, and melts readily before the blowpipe without vapour or fmell.

It is looked upon by Bournon as a proper double fulphuret of copper and iron. From the analyfis by Chenevix of feveral Corniſh fpecimens of a nickel-red colour, it appears to conſiſt of

60	to 65	Copper,
15	— 18	Iron,
17	— 25	Sulphur.

Klaproth has analyfed two fpecimens, one from Hitterdahl in Norway, and the other from Rudelftadt in Silefia, with the following refult.

69.5	— 58	Copper,
19	— 19	Sulphur,
7.5	— 18	Iron,
4	— 5	Oxygen.
100.0	100	

It is to be obferved however that the oxygen in thefe analyfes was only inferred from the deficiency of the three firft ingredients when compared with the whole quantity previous to analyfis.

This ore occurs in beds, veins, and difleminated in rocks of different formations: it appears however to be moft frequent in primitive beds. It is ufually accompanied by vitreous copper and copper-pyrites, and not unfrequently by garnet. It is found in Cornwall, and in moft of the copper-mines on the Continent.

† Sp. VI. Grey Copper. *Fahlerz*, Werner. *Cuivre gris*, Hauy.

Its ufual colour is fteel-grey of more or lefs intenfity, which often paffes into iron-black and lead-grey; fome varieties incline towards yellow, and others again prefent fuperficial iridefcent colours. It occurs in maffs or difleminated, or inveſting, and is then often fpecular, or cryftallized in regular tetrahedrons and their modifications. The cryftals are fmall and rarely middle-fized, with fhining furfaces. Internally it is gliftening or fhining, with a metallic luftre. The fracture is coarfe and fmall grained uneven, inclining to imperfect-conchoidal. It gives a black powder paffing into reddifh-brown. It is moderately hard, brittle and eafily frangible. Sp. gr. when pure 4.46 to 4.56, that of the more compound varieties rifes to 4.86.

It is confidered by Bournon as a proper double fulphuret of copper and iron, and differs from the preceding fpecies in colour, cryftalline form, fpecific gravity, and proportion of component parts. Some brilliant cryftals of this fpecies, in the form of tetrahedrons with doubly bevilled edges and the folid angles truncated, from Cornwall, were analyfed by Chenevix, and found to conſiſt of

52	Copper,
33	Iron,
14	Sulphur,
99	

A fimilar refult was alfo obtained from the analyfis of fome fpecimens of the fame in maſs. But though copper, iron and fulphur appear to

be the only neceſſary ingredients of this ore, yet it is moſt frequently found to contain alſo antimony, ſilver and lead, though in extremely variable proportions. Some varieties from Tranſilvania, Alſace, the Hartz, Saxony, Heſſia and Dauphiné, examined by Mr. Chenevix, were found to contain, beſides the ſubſtances above mentioned, a portion of antimony varying from 5 to 38 *per cent.* but neither lead nor ſilver. Two of the more complicated ſpecimens, one from Cremnitz and the other from Andreaſberg, have been analyſed by Klaproth with the following reſults:

Copper	31.36	—	16.
Iron	3.30	—	13.
Sulphur	11.5	—	10.
Antimony	34.09	—	16.
Silver	14.77	—	2.25
Lead	0	—	34.
Silex	0	—	2.5
	95.02		93.75

Finally, a ſpecimen from Piedmont has been examined by Napione, and found to conſiſt of

Copper	29.3
Iron	12.1
Sulphur	12.7
Antimony	36.9
Silver	0.7
Arſenic	4.
Alumine	1.1
	96.8

It occurs in veins in ſlate and ſome other of the neweſt primitive rocks, and in beds in the tranſition and floetz-rocks. It is accompanied by copper-pyrites, galena, manganeſe, ſpathoſe iron, quartz, heavy ſpar and fluor, alſo, though rarely, with malachite and azure copper. When it contains a notable proportion of ſilver, it is worked as an ore of that metal, and will accordingly be mentioned again under ſilver.

It is found in Cornwall and Ayrſhire, and in many parts of the Continent.

Sp. VII. Copper Pyrites. *Yellow Copper ore*, Kirw. *Kupferkies*, Werner. *Pyrite cuivreuſe*, Hauy and Brochant.

Its colour is a deep braſs-yellow verging into gold-yellow: its ſurface is often irideſcently tarniſhed. It occurs in maſs, diſſeminated, ſuperficial, in particular ſhapes ſuch as ſtalactitical, cluſtered, dendritical and reniform: alſo cryſtallized in tetrahedrons and the derivative octahedron and dodecahedron. The cryſtals are ſmall and very ſmall, and generally difficult to aſcertain. The ſurface of the cryſtals is ſmooth and ſhining, the other varieties are rough and glimmering, The fracture is commonly uneven with coarſe or fine grains; the coarſe-grained paſſes into imperfect and ſmall conchoidal, and thence into imperfectly foliated; the fine-grained paſſes into uneven, even, and flat-conchoidal; the colour of the foliated is gold-yellow, and it has alſo the ſtrongeſt luſtre. It is brittle, and with difficulty gives a few feeble ſparks with the ſteel: it is eaſily frangible. Sp. gr. 4. to 4.1.

When expoſed to the blowpipe on charcoal it decrepitates, emits a ſulphureous vapour, and melts into a black globule, which by continuing the heat acquires the colour and luſtre of metallic copper.

It does not appear that the cryſtallized varieties of this ore have as yet been ſubjected to analyſis, and the proportion of its conſtituent parts cannot be eſtimated from the other varieties on account of the iron pyrites which is always blended with them in greater or leſs quantity. A ſpecimen examined by Lampadius afforded

41.	Copper,
17.1	Iron,
45.1	Sulphur.
103.2	

In this analyſis the copper and iron were reduced to the metallic ſtate, ſo that the ſulphur (probably for want of ſufficient drying) is eſtimated too high. In general however the produce of copper from this ore does not exceed more than about 20 *per cent.* and in favourable ſituations it is reckoned worth working when it does not yield more than 5 or 6 *per cent.* A good deal of confuſion is obſervable among mineralogical writers in treating of copper pyrites, ſome conſidering it as a peculiar ſpecies, while others reckon it only as a variety of iron pyrites holding a variable proportion of copper; and this confuſion has been ſtill further increaſed by aſſayers and metallurgiſts, who rank as yellow copper ore every ſpecimen of a yellow colour and metallic luſtre, from which a notable proportion of copper can be extracted. It is however neceſſary to diſtinguiſh between copper pyrites, which appears to be a proper double ſulphuret of copper and iron, and of which in the cryſtallized varieties the proportions of the three ingredients are probably permanent; and iron pyrites holding an accidental and variable proportion of copper. Of the former the primitive figure is a regular tetrahedron, its colour

is a golden yellow, it has a brilliant luſtre and an uneven granular, or ſmall conchoidal fracture; it is eaſily ſcratched by iron pyrites, and its ſpecific gravity does not exceed 4.1. Cupreous iron pyrites on the contrary cryſtallizes in cubes and their modifications, has little luſtre, is of a braſs-yellow colour, an uneven fracture, gives plentiful ſparks with ſteel, and its ſpecific gravity is about 5. . The octahedral figure is common to both, as being a modification of the tetrahedron and cube, but the other diſtinctive characters are permanent. Of the maſſive amorphous varieties, from which the greater part of the manufactured copper is procured, it is probable that the poorer kinds, as moſt of the Welch, are chiefly cupreous iron pyrites, while the richer ones of Cornwall are copper pyrites, mixed more or leſs with miſpickel.

Copper pyrites is the moſt abundant and generally diffuſed of all the ores of copper. It occurs in veins and beds in primitive, tranſition, and ſecondary rocks. In Britain it is found principally in the counties of Cornwall, Derby, Angleſey, and Caernarvon, or in Mainland, one of the Shetland iſlands.

Sp. VIII. Black Copper. *Kupferſchwarze*, Werner. *Cuivre noir*, Brochant.

Its colour is intermediate between bluiſh and browniſh black. It occurs in maſs or diſſeminated or inveſting. It is compoſed of dull moderately cohering earthy particles. It is friable, ſlightly ſoils the fingers, is meagre to the feel, and heavy.

Before the blowpipe it emits a ſulphureous odour, and melts into a ſlag that colours borax green.

It uſually occurs with copper-pyrites, malachite, mountain-green and vitreous copper. It is found in Saxony, Hungary, Sileſia, Norway, and Siberia; and at Orme's Head in Caernarvonſhire in limeſtone, accompanied by copper-pyrites, malachite, calcareous ſpar and pearl-ſpar.

IV. Family. Arsenicated Copper.

Sp. IX. White Copper. *Weiſs Kupfererz*, Werner. *Mine de Cuivre blanche*, Brochant.

Its colour is intermediate between ſilver-white and braſs-yellow. It occurs in maſs or diſſeminated. Internally it has a ſlight metallic luſtre. Its fracture is ſmall and fine-grained uneven. It yields eaſily to the knife, is brittle and readily frangible. Sp. gr. 4.5.

Before the blowpipe it yields a white ſmoak with an arſenical odour, and melts into a greyiſh black ſlag. According to Henkel it yields 40 per cent. of copper, the remainder being iron, arſenic and ſulphur.

It occurs in veins and beds in primitive mountains, and is generally accompanied by copper pyrites and vitreous copper. It is found in the copper mines of Cornwall, Saxony, Heſſia, Sileſia, Hungary, Siberia, and Chili in South America.

By its colour and arſenical odour when heated, it is diſtinguiſhed from the ſulphurets of copper; and from arſenical pyrites by its inferior ſpecific gravity.

V. Family. Carbonated Copper.

Sp. X. Azure Copper or Mountain-blue. *Kupferlazur*, Werner. *Azur de Cuivre*, Broch. *Cuivre carbonaté bleu*, Hauy.

Of this there are the two following varieties.

Var. 1. Radiated A. C. *Feſte K.* Werner. *A. de C. rayonné*, Brochant.

Its principal colour is azure-blue, which paſſes into Pruſſian-blue, indigo blue, and rarely to ſmalt-blue. It occurs ſometimes in maſs, diſſeminated or inveſting, more frequently botryoidal, ſtalactitic and cellular, but moſt frequently cryſtallized. Its primitive form is that of an octohedron with ſcalene triangular faces; but its uſual figures are, an oblique rhomboidal priſm, either ſimple or terminated by two oppoſite triangular facets and dihedral ſummits, and an octohedral priſm with dihedral ſummits. The cryſtals are generally ſmall and very ſmall, aggregated into globular or cluſtered maſſes or bundles. The broad faces of the priſms are ſtriated in the direction of their breadth, the narrow faces on the contrary are ſtriated lengthwiſe, and all the other ſurfaces are ſmooth. The cryſtallized varieties are externally ſhining, but the reſt are dull. Internally it is ſhining or gliſtening with a luſtre between vitreous and reſinous. Its fracture is ſtrait or divergingly radiated, rarely lamellar. The cryſtals are tranſlucent and ſemitranſparent, the other varieties are opake or at moſt tranſlucent on the edges. When pulverized it is of a ſky-blue colour. It is ſoft, brittle and eaſily frangible. Sp. gr. 3.2 to 3.4.

It is very difficult of fuſion before the blowpipe *per ſe*, but with borax it gives a bright-green glaſs and a metallic globule.

According to Pelletier it conſiſts of

66	to	70	Copper,
18	—	20	Carbonic acid,
8	—	10	Oxygen,
2	—	—	Water.

Var. 2. Earthy A. C. *Erdige K.* Werner. *A. de C. terreux*, Brochant.

Its colour is ſmalt-blue. It occurs rarely in maſs, generally diſſeminated or ſuperficial. It

is compoſed of fine, pulverulent, cohering, dull particles. Its fracture is fine grained earthy, paſſing occaſionally into even and imperfectly conchoidal. It is opake, ſlightly ſtains the fingers, and is eaſily frangible.

Before the blowpipe it becomes black but does not melt. In borax it diſſolves with vehement ebullition forming a green glaſs.

Azure copper occurs in the newer primitive rocks, but more commonly in floetz mountains. It accompanies other ores of copper, eſpecially malachite, grey copper and copper pyrites. The moſt beautiful ſpecimens come from the Bannat in Hungary and Siberia. In the Tyrol it is found in ſufficient plenty to be manufactured into the pigment called mountain-blue.

Sp. XI. Malachite. *Malachit*, Werner. *Malachite*, Brochant. *Cuivre carbonaté vert*, Hauy.

Of this mineral there are the three following varieties.

Var. 1. Fibrous M. *Faſriger M.* Werner.

Its common colour is graſs-green paſſing into emerald-green and ſometimes into dark leek-green. It ſeldom occurs maſſive or diſſeminated, but generally inveſting, and often cryſtallized in ſhort capillary needles, diſpoſed commonly in divergent bundles or ſtars. Externally they are ſhining, but internally only gliſtening with a ſilky luſtre. Its fracture is delicate diverging fibrous paſſing into coarſe fibrous. It is opake or tranſlucent on the edges, the cryſtals are for the moſt part tranſlucent. When pulverized it retains its colour, only the tint is ſomewhat lighter. It is very ſoft, brittle and eaſily frangible. Sp. gr. 3.5.

It effervesces with acids, and forms a blue colour with ammonia. Before the blowpipe it blackens and decrepitates, but is infuſible *per ſe*. With borax it melts into a green glaſs.

Its conſtituent parts according to Klaproth, are

58.	Copper,
18.	Oxygen,
12.5	Carbonic acid,
11.5	Water
100.0	

It occurs uſually in the newer primitive, and floetz mountains, accompanied by other ores of copper, alſo by carbonat of lead, calcareous ſpar, brown ſpar, and quartz. The fineſt ſpecimens of this variety of malachite are found in the Siberian and Hungarian mines: it occurs alſo in Saxony, and various other mining diſtricts in Germany, alſo in Norway, in the Mainland, one of the Shetland iſlands, in Cornwall, Derbyſhire, and Ormeſhead in Caernarvonſhire.

Var. 2. Compact Malachite. *Dichter M.* Werner. *M. compacte* Broch.

Its colour is emerald-green, paſſing into graſs and verdigris green; the ſame ſpecimen exhibiting different ſhades: its external ſurface is commonly overſpread with a greeniſh-white cruſt. It occurs maſſive, diſſeminated, and membranaceous, but moſt frequently reniform, cluſtered, mamillated, ſtalactitic, cellular, or globular. Externally it is rough and dull, or marked by black dendrites. Internally it is, according to the kind of fracture, either dull, gliſtening or ſhining. Its fracture is conchoidal or fine granular uneven, or minutely fibrous. It generally occurs in thin lamellar concentric diſtinct concretions, curved in the ſame direction as the ſurface, each of which has generally a different ſhade of colour, thus giving to the whole a ſomewhat banded appearance. It is opake, ſoft, brittle, and eaſily frangible. Sp. gr. 3.5 to 3.6.

Its chemical characters and component parts are preciſely ſimilar to thoſe of the preceding variety, with which it alſo agrees in its geognoſtic and geographical ſituation. In England it occurs at the Lands-end and other places in Cornwall, alſo both mamillated and diſſeminated in red ochery clay, accompanied by copper pyrites, in ſecondary limeſtone, at Llanymynech, Montgomeryſhire.

Compact Malachite, on account of its fine emerald colour, its variable ſattiny tiſſue and luſtre, and the high poliſh that it is capable of receiving, is an extremely ornamental ſubſtance, and much ſought after on this account. The largeſt and fineſt ſpecimen that is known was procured in Siberia, and graced the cabinet of Count Lanſkoi at Peterſburg, after whoſe death it paſſed into the collection of Dr. Guthrie, where it probably ſtill remains. It is a plate about 35 inches long, 18 broad, and above 2 in. thickneſs, and is valued at 800 pounds ſterling.

Var. 3. Earthy Malachite. *Kupfergrün* Werner. *Vert de Cuivre* Broch.

Its principal colour is verdegris-green, paſſing ſometimes into emerald-green or ſky-blue. It occurs in maſs, diſſeminated, or inveſting. Internally it is ſhining, paſſing into gliſtening, with a reſinous luſtre. Its fracture is ſmall conchoidal. It is tranſlucent and ſemitranſparent; is ſoft and eaſily frangible.

Its chief chemical character is that of giving little or no effervescence when diſſolved in acids.

It has not been analyſed. It is found in ſimilar ſituations with the other varieties of malachite, but is of much rarer occurrence.

Sp. XII. Emerald Copper. *Kupfer-Schmaragd* Werner. *Dioptaſe* Hauy.

Its colour is emerald-green. It occurs cryſtallized in lengthened dodecahedrons, its primitive form being that of an obtuſe rhomboid. It is ſhining both externally and internally, and has a vitreous luſtre. It is tranſlucent, paſſing to ſemitranſparent; ſcratches glaſs feebly and with difficulty; is brittle. Sp. gr. 3.3.

Before the blowpipe it becomes of a cheſnut-brown colour, and communicates to the flame a greeniſh-yellow tinge; it is infuſible *per ſe*. With borax it gives a bead of copper, According to the analyſis of Vauquelin, it conſiſts of

Oxyd of copper	25.57
Carbonat of lime	42.85
Silex . .	28.57
	96.99

It has hitherto been found only in Daouria, on the Ruſſian and Chineſe frontiers, in a vein accompanied by malachite.

VI. Family. Arseniat of Copper.

Sp. XIII. Octohedral Arſeniat of Copper. *Oktaedriſches Olivenerz* Karſten.

Its uſual colour is deep ſky-blue, paſſing into Pruſſian-blue; it is alſo found of a bright graſs-green, paſſing into apple-green, greeniſh-white, and bluiſh-white. It occurs in obtuſe octohedrons, formed by two tetrahedral pyramids with iſoſceles triangular planes, united baſe to baſe. The four planes however ſeldom terminate in one point, hence the apex is lengthened to a ridge, and the baſe, inſtead of being a parallelogram, approaches near to a ſquare. The ſurfaces are ſhining and ſmooth, or ſtriated parallel to their edges. The cryſtals are implanted in cavities; they have a ſhining vitreous luſtre and a lamellar fracture, are ſemitranſparent, ſometimes tranſparent. Their hardneſs is inferior to that of fluor ſpar. Sp. gr. 2.88.

Its conſtituent parts, according to Chenevix, are

49	Oxyd of copper
14	Arſenic acid
35	Water
98	

It is found in Huel-Gorland mine in Cornwall, in veins accompanied by vitreous copper, copper pyrites, arſenical pyrites, and iron ochre.

Sp. XIV. Hexahedral Arſeniat of Copper. *Blattriges Olivenerz* Karſten.

Its colour is deep emerald-green, paſſing to verdegris-green. It occurs cryſtallized in thin hexagonal tables. The broad planes are ſmooth and brilliant, with a metallic luſtre. It is tranſlucent, ſofter than calcareous ſpar. Sp. gr. 2.54.

When placed on hot coals it decrepitates ſtrongly; its component parts, according to Chenevix, are

58	Oxyd of copper
21	Arſenic acid
21	Water
100	

It occurs in the ſame mine as the preceding ſpecies, and is principally accompanied by ruby copper.

Sp. XV. Priſmatic Arſeniat of Copper. *Priſmatiſches Olivenerz* Karſten.

Its colour is browniſh, or dark bottle-green, verging ſometimes to yellowiſh, in which caſe it generally reflects the light of a golden tint, when capillary it is of a lighter and brighter colour. It occurs cryſtallized in an irregular acute octohedron with a rectangular baſe (which is its primitive form), or in a long rhomboidal or flattened hexahedral priſm with dihedral ſummits, or capillary, either in very lengthened octohedrons or indeterminate. Sometimes the cryſtals are regular at one extremity, and terminate in capillary bruſhes at the other. The cryſtals are ſmall, and are accumulated laterally or implanted. It has a conſiderable luſtre between vitreous and reſinous; is tranſlucent, paſſing to tranſparent; is harder than fluor, but will not ſcratch glaſs. Sp. gr. 4.28.

It paſſes into the two following varieties.

1. Amianthiform.

Its colour varies from bluiſh-green to graſs-green, brown-green, golden-brown, golden-yellow, ſtraw colour, and white. It occurs in extremely minute parallel or diverging flexible fibres, or thin duſty flexible laminæ, with more or leſs of a ſattiny luſtre.

2. Hematitiform.

Its colour is browniſh or whitiſh-yellow. It occurs in flat or mamillated layers either ſmooth or covered with little rough cryſtalline points. Its texture is fibrous, but very compact, reſembling wood tin.

This ſpecies with the Capillary and Hematitiform varieties has been analyſed by Mr. Chenevix, with the following reſult.

	Priſmatic.	Capillary.	Hematitiform.
Oxyd of copper	60.	51	50
Arſenic acid	39.7	29	29
Water . . .	0	18	21
	99.7	98	100

It is found in Huel Gorland mine in Cornwall.

Sp. XVI. Trihedral Arſeniat of Copper.

Its colour is deep bluiſh-green, paſſing to black when in a ſtate of decompoſition. It occurs cryſtallized, in a trihedral priſm, whoſe baſes are equilateral triangles (which is its primitive form), ſometimes one of the edges of the priſm is replaced by a plane parallel to the adjacent ones, forming a tetrahedral priſm; ſometimes the plane that replaces the edge of the priſm is conſiderably inclined ſo as to diminiſh and even obliterate one of the baſes, thus forming a wedge-ſhaped figure with ſcalene triangular ſides. It alſo occurs in tetrahedral and hexahedral priſms, in very acute rhomboids, and irregular octohedrons; alſo capillary and mamillated like the preceding ſpecies. The cryſtals are ſmall and very ſmall, when unaltered are tranſparent but become opake by decompoſition. It is ſhining, ſcratches calcareous ſpar, though with difficulty. Sp. gr. 4.28. Its component parts, according to Chenevix, are

Oxyd of copper	54
Arſenic acid	30
Water .	16
	100

Sp. XVII. Martial Arſeniat of Copper.

Its colour is bright ſky-blue. It occurs cryſtallized in a compreſſed rhomboidal tetrahedron, terminated at each extremity by a four-ſided pyramid, the faces of which are ſcalene triangles. The priſm is ſometimes hexahedral, on account of the obtuſe edges of the rhomboid being replaced by ſecondary planes; or octohedral when all the four edges are replaced. The cryſtals are very ſmall, and are generally grouped together in ſmall ſpheres. It is ſhining, tranſparent, ſomewhat harder than calcareous ſpar. Sp. gr. 3.4.

It is compoſed, according to Chenevix, of

Oxyd of copper	22.5
—— iron	27.5
Arſenic acid	33.5
Water -	12.
Silex -	3
	98.5

It occurs in Muttrel mine, adjoining to Huel Gorland, accompanied by the ſame ſubſtances as the preceding ſpecies.

VII. Family. Phosphat of Copper.

Sp. XVIII. Phoſphat of Copper.

Its colour externally is greyiſh-black, internally between emerald and verdegris-green. It occurs in maſs, diſſeminated, and cryſtallized in rhomboids, with convex lateral planes. The cryſtals are ſmall and very ſmall, their ſurface is druſy, and ſhining with a high vitreous luſtre. Internally it is gliſtening with a ſilky luſtre. Its fracture is delicate and diverging fibrous. It is opake, and moderately hard. It conſiſts, according to Klaproth, of

68.13	Oxyd of copper
30.95	Phoſporic acid
99.08	

It has hitherto been found only at Firneberg in Cologne, in white druſy quartz. It was formerly miſtaken for a variety of malachite.

VIII. Family. Muriat of Copper.

Sp. XIX. Sandy Copper. *Saltzkupfererz* Werner.

Its colour is emerald-green, paſſing into leek and olive-green. It occurs maſſive, diſſeminated, and cryſtallized in extremely minute ſix or four-ſided priſms. The ſurface of the cryſtals is ſmooth and brilliant, and their fracture lamellar. The maſſive variety is opake, the cryſtals are tranſparent. It occurs in coarſe and ſmall granular diſtinct concretions. It is ſoft and eaſily frangible. Sp. gr. 4.43.

Before the blowpipe on charcoal it tinges the flame of a bright green and blue colour, and a metallic bead remains behind. It is ſoluble in nitrous acid without efferveſcence, and almoſt entirely in ammonia. The following are its conſtituent parts according to Prouſt and Klaproth,

Prouſt		Klaproth	
From Peru	Chili	Chili	
76.595	70.482	73	Oxyd of copper
10.638	11.446	10.1	Muriatic acid
12.767	18.072	16.9	Water
99.99	100.	100.0	

It is found looſe in the bed of a river at Remolinos in Chili, and elſewhere, though rarely, in Spaniſh South America.

Reduction of the Ores.

The reduction of copper ores in the large way is on the whole a very ſimple buſineſs, being little elſe than a ſucceſſion of roaſting and reducing proceſſes of the ſimpleſt kind, till the metal acquires the deſired degree of malleability and purity. It is to be obſerved that both arſenic and ſulphur adhere to copper with great

obſtinacy, even long after it has aſſumed the appearance of a pure regulus, and even in very ſmall proportion they make the metal brittle, hard, and difficult to work.

There are ſcarcely two works in which preciſely the ſame order is obſerved in the different reducing proceſſes (ſuppoſing the quality of the ore to be the ſame) and as the manufacturer is generally ſatisfied with that which has been long eſtabliſhed and is attended with ordinary ſucceſs, he ſeldom enquires whether the labour may be ſhortened or the expence diminiſhed.

The ſulphuret of copper which is obtained in ſuch vaſt quantities at the Parys mine in Angleſea, is wrought into rough copper in the following manner. The ore is dug up in large pieces (being moſtly obtained by blaſting) and is firſt broken into ſmalliſh lumps by the hammer, chiefly by women and children, and put into a kiln from which proceed flues that open into a very long cloſe pent-houſe gallery to collect the ſulphur. The kiln is covered cloſe, and a little fire is applied to the maſs of ore in different places, whereby the whole is gradually kindled. The ſulphur then riſes in vapour to the top of the kiln, and thence through the flue into the long gallery, where it ſlowly condenſes, and is afterwards bruſhed out and further prepared for ſale. The maſs of ore when once kindled continues to burn of itſelf with a ſmouldering heat for about ſix months, during which time the ſulphur-chamber is cleared out four times, after which the ore is ſufficiently roaſted. The old ſulphur-chambers are on a level with the kilns and of the ſame length and height, or in fact they are a prolongation of the kilns: but the more modern and improved chambers are like lime-kilns, the ore being at the bottom, and the ſulphur ſubliming at the top, with a contrivance to take out the roaſted ore, and thus to keep up a perpetual fire.

The richeſt part of the roaſted ore is exported without further preparation, but the pooreſt part is ſmelted on the ſpot. It ſtill contains a vaſt quantity of ſulphur and other impurities. The ſmelting houſes are a range of large reverberatory furnaces, thirty-one of which are under the ſame roof, ranged ſide by ſide in a ſingle long row. They are all air furnaces, the chimneys of which are 41 feet high, which cauſes a moſt powerful draught through them. The fuel is coal, which is burned on a grate at the anterior part of the furnace, and the flame in drawing up the chimney paſſes over the bed of the reverberatory, into which is put 12 cwt. of the roaſted ore, previouſly mixed with a ſmall portion of coal duſt. The ore is here melted and reduced into a very impure regulus, and when ſufficiently fuſed it is drawn off through a plug-hole into earthen moulds. A ſingle charge of the furnace, or 12 cwt. yields ½ a cwt. of rough copper, which by further purification affords about 50 per cent. of pure malleable metal. The furnaces work off a ſingle charge about every five hours.

The copper furnaces in Cornwall are alſo of the reverberatory kind. The ore when drawn up from the mine is firſt broken into pieces no bigger than a hazel-nut, which operation is called *cobbing*, and the better ſort is picked out by hand. The reduction begins by the proceſs of roaſting in large reverberatory furnaces 14 feet by 16, the bottom or bed of which is made of fire-bricks and covered to the thickneſs of about 2 feet with ſilicious ſand, which runs together by the heat into a ſemi-vitrified maſs. The chimney is from 40 to 50 feet high, which cauſes ſuch a powerful draught that the arſenic and ſulphur ſeparated during the roaſting paſs almoſt entirely through the chimney into the open air, none of it being collected as at Angleſea. The ore is ſpread over the bottom of the furnace about a foot thick, being thrown in through a kind of funnel or hopper juſt above. The fuel is Welſh coal, which, as uſual, is burnt at the anterior part of the furnace, and its flame draws over the ſurface of the ore in its paſſage to the chimney. In this furnace, which is called the calcining furnace, and is the largeſt of all, the ore is roaſted without addition with a dull red heat for 12 hours, and is frequently in that time ſtirred with a long iron rake, introduced through a hole at the further end of the reberveratory, to expoſe freſh ſurfaces to the action of the flame. The ore is not melted here, but when roaſted ſufficiently, it is carried to another furnace exactly ſimilar to the former, but ſmaller, that is, about 9 feet by 6, and here it receives a fuſing heat, but ſtill without any addition, except that when the ſlag does not riſe freely, a little calcareous ſand is thrown in. At the end of every four hours the ſlag is raked out; it is then of the conſiſtence of ſoft dough and is laded into oblong moulds, and a little water is ſprinked upon it to make it ſink down, after which the moulds are quite filled with it, and when cold it makes hard ſolid blocks of ſlag about 14 inches long and 12 deep and broad, which are uſed for building. After the ſlag is raked off, a freſh charge of calcined ore is let down into the reverberatory, and the copper is tapped off by a hole in the ſide of the

furnace, which before the fuſion had been ſtopped up with a ſhovel full of wet clay mixed with about a fourth of new coal, which prevents the clay from hardening too much, ſo that the hole may readily be opened by an iron pick.

The rough copper as it runs from the furnace is conveyed by a gutter into a large kind of bucket ſuſpended by chains in a well through which a ſtream of water is paſſing, and here, in falling into the water, the metal is granulated, which takes place without exploſion or danger, and it is then drawn out by raiſing the bucket.

The copper is ſtill however extremely impure, though apparently in the metallic ſtate, being grey and perfectly brittle, and ſtill mixed with arſenic and ſulphur, to ſeparate which is the work of ſeveral ſubſequent proceſſes. It is then remelted and granulated twice more or oftener, each time throwing up a ſlag in the furnace, which is removed before the plug-hole is tapped; but as this ſlag contains ſome copper, it is not caſt into moulds as the firſt, but worked over and over again with the freſh charges of calcined ore. The number of fuſions and granulations is entirely determined by the nature of the ore. The granulated maſs is then melted and caſt into pigs, which have a bliſtered appearance on the ſurface, and are broken up and roaſted for one or two days in a low red heat, and again melted and roaſted as before for ſeveral times till the metal is conſiderably purer, and at laſt is caſt in oblong iron moulds about 14 inches in length, when it is removed to the *Refining Furnace*. Here it is again melted with the addition of a little charcoal, till it is brought to a ſufficient purity to bear the hammer, and is now good ſaleable copper.

It is obſervable that in the former proceſs when the crude and brittle metal is caſt in ſand in the form of large pigs or ingots, the beſt part of the copper riſes to the ſurface, and when cold may be knocked off with a hammer, forming a brittle cruſt about three-quarters of an inch thick, of a grey colour and a ſteel-like fracture.

Thus by a ſeries of ſucceſſive calcinations and fuſions in the ſimpleſt manner poſſible, the common copper ores are freed from arſenic, ſulphur and earthy matters, and gradually brought to the ſtate of malleable copper. Where a variety of ores from different places and of different ſpecies are brought to the ſame ſmelting-houſe (which is the caſe in many of the houſes at Swanſea and different parts of the Briſtol coaſt) much technical judgment is exerciſed in ſorting the ores and diſtributing the charges for the furnace in ſuch a manner that the more fuſible will aſſiſt the reduction of the refractory, and the poorer will be made more worth working by the addition of a portion of the richer ores, and the like.

The ſubſequent operations whereby the ingots or pigs of malleable copper are formed into ſheet copper, wire, nails, bolts, cauldrons, and an infinite variety of manufactured articles, do not come within the province of pure chemiſtry: it may be ſufficient to obſerve that the hammering renders the metal much more uniform, cloſe, and ductile, but this requires to be frequently alternated with annealing at a full red heat, to prevent the metal from cracking under the powerful preſſure to which it is expoſed. Immediately after the laſt annealing, the copper plates are quenched in urine, which ſomewhat hardens the ſurface, and gives it that redneſs which is conſidered by the merchant as one mark of the purity of the metal.

In the reduction of the copper ores of Neuſol in Hungary, lead is uſed in the refining part of the proceſs [b] in the following manner: the rough copper is ſpread on the bed of a furnace, and when it has been ſix hours in fuſion, ſome lead, in the proportion of from 6 to 8 per cent. of the copper, is thrown in, which immediately begins to vitrify and to form a thick ſcoria along with the impurities of the copper, which is ſcummed off ſucceſſively till the whole is exhauſted and the copper remains fine and clear. This proceſs laſts from 10 to 12 hours, with 50 quintals of raw copper. The ſcoriæ retain a portion of copper, which makes it anſwer to work them again.

The power which the vitrified oxyd of lead has to ſcorify all metals, except gold, ſilver and platina, is amply ſhewn in the proceſs of *Aſſaying*, and hence it muſt happen that in refining, ſome of the copper becomes oxidated together with the lead; but the ſame proceſs of aſſaying ſhews that copper requires a large portion of lead for this purpoſe, and therefore the latter metal in ſo ſmall a proportion as 6 to 8 per cent. is probably a moſt uſeful addition where not too expenſive. For of all the common imperfect metals, copper is that which ſcorifies and oxidates with moſt difficulty when in fuſion, and therefore the ſame method, with ſome little variety, may be practiſed to ſeparate lead and tin (for example) from copper, as any or all of theſe metals from ſilver or gold, care being taken in the former caſe not to carry the ſcori-

fication beyond what is neceſſary to ſeparate the more eaſily oxidable metals from the copper which then remains in the metallic ſtate. This will be further noticed in the ſucceeding article of *Alloys of Copper*, and the purification of bell-metal. After the greater part of the lead has been worked off as often as is judged neceſſary, the remaining copper muſt be kept for a while longer in fuſion, to throw up the laſt portions of lead that may adhere. In aſſaying gold or ſilver the total expulſion of the lead is known by the fine metal becoming at once brilliant on the ſurface, but in refining copper this appearance can never take place, as the copper itſelf always forms a thin oxyd on its melted ſurface; and therefore, to judge whether it is pure, the workman dips a poliſhed iron rod in the melted maſs, and draws out a portion of copper adhering to it, which, if pure, immediately falls off when the rod is dipped in water. The colour of the ſcoria is alſo another teſt. While the copper remains impure and alloyed with iron, ſulphur, &c. the vitrified oxyd on the ſurface is black or of a dirty brown, but the ſcoria of pure copper is red, and alſo is readily ſeparated from the iron when cold, leaving no ſtain behind.

The plates of fine red copper, called *Roſette Copper*, are made in the following way.[c] When the refined copper is found by the way juſt mentioned to be ſufficiently pure, the ſurface of the melted metal is well ſcummed and ſuffered to cool till it is ready to fix, at which time a workman bruſhes it over with a wet broom, which immediately fixes the ſurface and cauſes a thin plate to ſeparate from the ſtill fluid metal below. This plate is taken off and thrown into water, where it takes a high red colour, and the ſame proceſs of wetting the ſurface is repeated with the remaining fluid metal ſucceſſively, till the whole is reduced to theſe thin irregular plates.

A conſiderable quantity of copper is obtained from the ſprings of native ſulphat of copper or blue vitriol, which are found in moſt copper mines or flow from hills containing this metal. To obtain it, the vitriol water is pumped up into large ſquare open pits, two or three feet deep, made with rammed clay, into which is thrown a quantity of refuſe iron of any kind, and ſuffered to remain for a conſiderable time, during which the iron is diſſolved, diſplacing by ſuperior affinity the copper which is precipitated in the form of a brown mud. When the water is thus exhauſted of its copper, the pits are raked out, and the oxyd collected from them is ſimply dried in the ſun. It is then fit for reduction in the reverberatory furnaces in the uſual manner. This is by far the richeſt material employed, for, though containing ſome clay and iron mixed with the copper, it yields on an average full 50 per cent. of pure metal, and therefore it is ſeldom ſmelted by itſelf, but mixed with the poorer ores, ſome of which contain no more than 5 per cent. of metal.

Many of the fineſt copper ores contain ſo much ſilver as to make it worth while to extract this laſt metal by a ſeparate operation, which will be deſcribed under the article *Silver*. In all the different roaſtings and reductions neceſſary to bring the copper to purity, the ſilver remains united with it.

Analyſis of Copper Ores.

The number of the analyſes made of the different ſpecies of copper ores is ſo immenſe, that a ſelection only of the moſt approved can here be given; and a few general rules may be premiſed, which will ſimplify the ſubject.

The analyſis of ores is uſually conducted in one of two diſtinct ways, the *dry* and the *moiſt*, each of which has its peculiar advantages and defects.

In the dry way, the ores when they contain ſulphur or arſenic (which is the caſe with the greater number) are firſt *roaſted* in order to diſſipate the greater part of theſe mineralizing ſubſtances. For this purpoſe, in analyſis in the ſmall way, they are mixed with about their bulk of charcoal powder (or better with fine ſaw-duſt) and expoſed to a low red heat on a flat tile or muffle, or any other convenient apparatus on which they can be thinly ſpread. The ſulphur or arſenic ſoon begins to riſe in fumes which ſhould be haſtened by frequent ſtirring, keeping the heat juſt below the point at which the ore would run and clot together, to prevent which is one conſiderable uſe of the charcoal or ſaw-duſt.

When no more fumes ſenſibly ariſe, and the charcoal is entirely burnt off, the part of the ore that remains now conſiſts of the metallic portion in the ſtate of an oxyd, ſtill mixed however with a quantity of ſulphur or arſenic, which mere roaſting will not ſeparate, and of all the earthy matrix that may have been originally contained.

The ore is then fitted for the ſecond proceſs, which is that of *reduction* of the metallic oxyds to the reguline ſtate. All that is eſſentially neceſſary to reduction is, to expoſe the oxyd to a

[c] Macquer. Chem. Dict.

high heat in contact with charcoal or carbonaceous matter of any kind, and secluded from the contact of air. In reducing the metals volatile in heat, such as zinc or antimony, this reduction requires somewhat of a different apparatus from the fixed metals, to which chiefly the present observations apply. It has been a constant custom with chemists in almost all cases (till of late years) to add to the ore in reduction, not only a due quantity of carbonaceous matter, but also to mix it with a large proportion (seldom less than thrice its weight) of some alkaline or easily vitrifiable matter to serve as a *flux* to promote the fusion of all the heterogeneous contents of the ore, and to afford a thin-flowing medium, through which the globules of reduced metal can readily fall by their superior gravity, and at last be collected in a single mass or button at the bottom of the crucible.

In all the common processes of reduction, therefore, which are usually given, the additions to the ore are of two kinds, the purpose of which should be well distinguished, namely, the carbonaceous matter, which is essential to the disoxygenation of the metallic oxyd, and the saline or fusible flux, the use of which is often highly convenient and even necessary, but also often needless or even detrimental. The invariable fault of saline fluxes as generally applied, is, that they always dissolve a portion of the metallic oxyd before it has time to pass to the metallic state, and retain it permanently, thus robbing the metallic button of a part of what otherwise would unite with it: and hence it almost invariably happens that common assays made in the dry way with saline fluxes return a less proportion of metal than the ore really contains. Nor is this loss trifling in many instances, since the accurate Klaproth found a difference of 9 per cent. between the yield of copper from a certain ore assayed in the dry way, and the same ore treated in a different manner, in the moist way. As a proof of the solution of a part of the metallic oxyd in the saline flux, it may be added that the scoria, or flux after melting, is always found deeply coloured with that precise tint which would be given, as in the common preparation of coloured glasses, by the designed admixture of the oxyd of the metal used. Thus the scoriæ of reduced cobalt ore are of a deep blue; of fine copper, green or brown according to circumstances; of iron grass-green, and the like. The loss of metal is still greater when the ore retains a portion of sulphur, which last uniting with the alkali, acts with still more power on the metallic oxyds.

As naked alkaline fluxes are peculiarly liable to this inconvenience, some eminent docimastic chemists employ with considerable success fluxes of equal power, but with less disposition to dissolve the metallic oxyds. Of this kind are very fusible glasses made of much alkali and silex without litharge or other metallic admixture, fluor spar, lime, and above all, borax. This last produces a thinner fusion of vitrifying mixtures than an equal quantity of any other substance whatever, and hence a smaller dose of this than of the naked alkalies, will answer all the purposes of a flux, and of course the loss by solution of the metallic oxyd is much less.

A reduction of the sulphuretted ores is sometimes conveniently effected by a single operation which gives a button of metal of considerable purity. The roasting, which is always a tedious operation, is saved by mixing the ore with two or three times its weight of nitre, and projecting it into a hot crucible. The mixture dephlagrates on reaching the crucible, the sulphur is burnt and converted to sulphuric acid which unites with the potash of the decomposed nitre, and the metal, now freed from the sulphur, becomes fully oxygenated by the nitric acid and ready for reduction. This is effected by throwing in a reducing flux of tartar and pitch or any similar matter, and applying a strong heat for the requisite time.

It appears, however, that though nitre is often a good and expeditious method of freeing ores from their sulphur, it is better not to perform the whole reduction in a single operation, but first to separate the metallic oxyd after dephlagration (which may be done by washing) and then to reduce it by a proper flux.

The reduction of the pure oxyds or carbonated oxyds of copper, whether natural or artificial, is effected without loss, and in by far the best method, simply by heating intensely in contact with charcoal in a covered crucible. This is in fact a very close imitation of the method of reduction in the large way of the roasted copper ores, only as these latter still contain sulphur, arsenic, iron, and other foreign matters, the process requires to be repeated many times before the copper is in a pure malleable state, in each of which, the impurities separate in the form of a thick pasty scum, as already described, under the article of reduction in the large way.

In small experiments, where saline fluxes are

uſed, theſe impurities diſſolve in the flux (which is one of the great uſes of theſe ſubſtances) and one or at moſt two operations, will ſuffice.

When copper is pure (that is, of a ſaleable purity, for it is very rarely found abſolutely pure) it is ſoft, malleable, and of a beautiful brilliant yellow-red where recently cut or filed. On the contrary, when containing ſulphur, arſenic, or iron, it is black, denſe, ſonorous, brittle, and more of a vitreous than a truly metallic appearance. In this ſtate it is called *copper-matt*, or *black copper* by metallurgiſts. Subſequent melting in contact with air, or with fluxes, removes theſe impurities, and if the operation be judiciouſly performed, the loſs ſuſtained by the matt, in being converted into pure copper is principally that of the impurities; for it is a valuable property of this metal to be much leſs eaſily oxidated, ſcorified, and diſſolved by ſulphurets, than any of the metals with which it is uſually found mixed, and particularly than iron.

After all, however, the analyſis of copper ores in the dry way can only give an approximation to accuracy in the reſult, except in the treatment of the pure native oxyds or carbonats, which are indeed among the moſt valuable ores, but are thoſe which the ſeldomeſt come under the notice of the practical metallurgiſt.

The analyſis of copper ores in the moiſt way is performed in a tolerably uniform manner, the ore being firſt treated with an acid which diſſolves all the metallic part, leaving the ſulphur and ſilex; after which the different metals are ſeparately precipitated from the ſolution, either in the metallic ſtate, or in certain known forms of combination, from which the metallic portion can be accurately inferred.

The particular ſteps of many of theſe analyſes will be preſently given; the general mode of ſeparating copper from the metals with which it is alloyed is as follows: *from ſilver*, by adding to the nitrous ſolution of the mixed metals muriat of ſoda, which ſeparates the ſilver, as luna cornea, and leaves the copper:—*from lead*, by adding to the ſolution ſulphat of ſoda, which precipitates an inſoluble ſulphat of lead, and leaves the copper:—*from antimony*, by digeſting the mixed oxyds of copper and antimony with nitric acid, which diſſolves the copper and leaves the antimony:—*from iron*, by ſuperſaturating the mixed ſolution with ammonia, which rediſſolves the copper and leaves the oxyd of iron; or elſe by immerſing a piece of poliſhed iron in the ſolution, which will ſeparate the copper and leave the iron in ſolution, (a precaution to be obſerved here, however, will be preſently mentioned):—*from tin*, by immerſing a piece of metallic tin in the ſolution, which will precipitate the copper only:—*from arſenic*, by diſſolving in nitrous acid and adding acetite or nitrat of lead which will ſeparate the arſenic in the form of an inſoluble arſeniat of lead, and leave the copper. If an exceſs of lead remain, add ſulphat of ſoda, as above mentioned:—*from Nickel* in the following way: when this metal is found it is generally in conjunction with iron; and ammonia, which precipitates all the three metals from their acid ſolution, rediſſolves, when in exceſs, both the nickel and copper; but to obtain the copper ſingly, again ſuperſaturate with muriatic acid, and immerſe a piece of iron, which will ſeparate the copper, and leave the nickel diſſolved.

Copper is obtained ſeparate, in wet analyſis, in three ſtates, in each of which the weight may be taken, either in the metallic ſtate, or as the green carbonat, or as the black oxyd. If a piece of poliſhed iron is immerſed in an acid ſolution of copper it is almoſt inſtantly covered with a brilliant coating of metallic copper, owing to an exchange having taken place, a portion of the iron being diſſolved, and ſeparating an equivalent quantity of copper from the ſolution. As this proceeds, the precipitate of metallic copper increaſes, and incruſts the remaining iron, forming a bundle of ragged filaments which the ſlighteſt force will detach if the ſolution is ſufficiently diluted. At laſt the ſolution contains only iron, and the whole of the copper is thus obtained in the metallic ſtate, which only requires waſhing and drying. This precipitation is much aſſiſted by boiling for a ſhort time, eſpecially at laſt, without which indeed the laſt portions of copper will hardly ſeparate. The ſolution when purely cupreous is of a fine azure blue, but when converted to a ſolution of iron becomes green. It ſhould be remembered, however, that for a perfect ſeparation of copper from iron by this method, the ſolution ſhould be in the ſulphuric or muriatic acids and not the nitrous, for though iron will equally diſplace copper from the nitrous as from the other acids, the nitrat of iron is itſelf largely decompoſed by mere heat or expoſure to air, and lets fall a fully oxidated iron, which in this caſe mixes with the fine filaments of the reduced copper, and vitiates the reſult of the analyſis. When, therefore, it has been neceſſary to employ this acid in the previous part of the analyſis, the metallic contents ſhould either be firſt precipitated by an alkali and rediſſolved in muriatic acid, or the

nitric ſolution ſhould be evaporated to dryneſs, redilſolved in muriatic acid, and again dried and moderately heated for ſome time, whereby the nitrous acid is expelled, and a metallic muriat remains for further treatment.

Inſtead of iron, tin or eſpecially zinc may be uſed as the precipitant of the copper from its ſolution: theſe act more ſpeedily and with equal certainty. With either of theſe two, as their muriat is colourleſs, the total abſence of the copper (provided iron or nickel is not at the ſame time preſent) is ſeen by the ſolution becoming entirely void of colour.

Mr. Chenevix has alſo remarked [d] a ſingular circumſtance in theſe precipitations, which is, that if the acid, (particularly the muriatic) be in exceſs, a quantity of hydrogen is diſengaged, as occurs in the common ſolutions of theſe metals, and the whole of the copper is ſeparated in a very ſhort time. With muriat of copper, zinc, and an exceſs of muriatic acid, the ſeparation is ſurpriſingly rapid, and much advantage may be made of this fact in the analyſis of copper ores.

It is to be obſerved, however, that zinc will precipitate iron as well as copper from its ſolutions, but ſcarcely any of the iron will ſeparate till all the copper is precipitated. Thus if zinc is added to a mixed ſolution of ſulphat or muriat of iron and copper, the firſt precipitate is obviouſly copper and little elſe, but at the time when the ſolution begins ſcarcely to turn blue with ammonia, a black powdery oxyd of iron mixes with the copper. Even if no iron be contained in the cupreous ſolution, if there is an exceſs of acid, and *common* zinc (which always contains iron) be uſed, ſome of it will ſtill appear in the precipitate; the exceſs of acid appearing firſt to diſſolve both the zinc and iron, and the latter being again ſeparated by the zinc that remains. On this account, perhaps, iron is a more accurate reagent than zinc in theſe analyſes. As the muriat of copper ſeems to yield its metal with more eaſe than the ſulphat, it might perhaps be of uſe previouſly to convert the ſulphat into a muriat by the addition of common ſalt. The colour immediately changes to green, which is a proof of this change of the cupreous ſalt.

The report of the aſſay will probably be ſtill more accurate, if the precipitated copper, after being waſhed and dried, inſtead of being immediately weighed, is put into a ſmall crucible, moiſtened with a drop or two of oil, covered with borax, and ſtrongly heated for a few minutes whereby it becomes a ſolid button of good malleable copper.

The ſecond ſtate is that of the green carbonat. If carbonated potaſh or ſoda be added to a ſolution of copper, a green precipitate is formed, which, when waſhed and dried at the heat of boiling water, gives an uniform green powder. Its exact nature will be mentioned when deſcribing the carbonat of copper, but it may be here added, that 180 parts of this carbonat are equivalent to 100 of metallic copper, and may be reckoned as ſuch in all analyſes. But as the pure fixed alkalies give a precipitate which may occaſionally be confounded with this carbonat, this method of eſtimation is not quite ſo good as the following.

The third ſtate in which copper may be eſtimated is that of the black oxyd. If the green carbonat laſt mentioned (and it need not be waſhed with particular care nor dried) be boiled for a few moments in cauſtic potaſh, it at once ſhrinks conſiderably and becomes a deep browniſh black fine powder, which is a pure oxyd of copper in its higheſt ſtate of oxygenation. One hundred parts of this oxyd, well waſhed and dried in a low red heat for a minute or two, invariably contain eighty parts of pure metallic copper. The ammoniated copper gives the ſame oxyd when boiled with potaſh.

It is alſo produced at once by adding potaſh or ſoda to the acid ſolutions of copper, and *boiling for a minute or two* (which laſt is an eſſential circumſtance) and this is a better method of proceeding in analyſis, ſince an exceſs of carbonated alkali will redilſolve a part of the green carbonat, and vitiate the analyſis, whereas no ſuch effect is to be feared from an exceſs of the pure fixed alkalies at a boiling heat.

The leading ſteps of the actual analyſes of ſome of the principal copper ores by the moſt accurate chemiſts may now be given in a few words, as a ſpecimen of the mode of proceeding in different caſes.

Of the ores compoſed chiefly of copper, iron, and ſulphur.

The vitreous copper ore was thus analyſed by Klaproth. [e]

To 200 grains of the powdered ore muriatic acid was added in a boiling heat, which had no immediate effect, but on dropping in a little nitrous acid, ſolution began with violent diſengagement of nitrous gas. When every thing ſoluble was taken up, the ſolution conſiſted of a clear

[d] Phil. Tranſ. for 1801, p. 211.

[e] Eſſays, vol. i.

green liquor on which the ſulphur was floating. The inſoluble part amounted to 38½ grains, 37 of which were diſſipated by calcination and were ſulphur, leaving 1½ of ſilex behind. The ſolution was divided into two parts, one to aſcertain the copper, the other the iron.

Into the former a bar of poliſhed iron was immerſed, and by reſt 78½ grains of copper were precipitated. The other half was ſuperſaturated with ammonia, which firſt precipitated both the iron and copper, and then rediſſolved only the copper, leaving 3 grains of oxyd of iron, equal to 2½ of metallic iron. Hence the iron, copper, ſilex, and ſulphur were ſeparately eſtimated. The copper is preſumed to be in the metallic ſtate in this ore on account of the violent evolution of nitrous gas. It is to be obſerved that by a previous trial the ore was found by the teſts before deſcribed to be free from ſilver and lead, that is by giving no precipitate either with muriat of ſoda, of ſulphat of ſoda.

The variegated copper ore was aſſayed by the ſame eminent chemiſt in nearly the ſame manner. On account of its colour and its making much leſs effervеſcence with nitric acid, a portion of oxygen is ſuppoſed to be combined with it.

The ſame was aſſayed in the dry way by being mixed with one-fourth of its weight of charcoal and roaſted, then mixed with a fourth of colophony or roſin, and thrice its weight of black flux, and well fuſed. The reſult was a button of copper, but 10 per cent. leſs than the quantity of metal obtained in the moiſt way.

The yellow hæmatitic copper ore and the grey vitreous ore from Cornwall, were analyſed by Mr. Chenevix [f] nearly in the ſame manner as above deſcribed, only the whole ſolution was ſuperſaturated with ammonia, and the copper ſeparated from the ammoniated ſolution by boiling with potaſh, in the form of the black oxyd, of which 100 parts were eſtimated as equal to 80 of copper.

Ore of Silver, Copper, Iron, Antimony and Sulphur.

Klaproth's analyſis of the Fahlerz [g] deſerves a ſhort notice on account of the ſkill with which it was managed.

The ore was firſt digeſted repeatedly with nitric acid, which diſſolved ſomewhat leſs than half. From the ſolution muriat of ſoda ſeparated ſome ſilver, and it was then tried for lead by ſulphat of ſoda. It was next ſuperſaturated with ammonia whereby a precipitate was left, which by ſubſequent treatment was found to conſiſt of iron with a little alumine and ſilex. The ammoniated ſolution which now only contained copper, was ſuperſaturated with ſulphuric acid, and the copper ſeparated by iron.

The firſt reſidue untouched by the nitric acid (amounting to more than half the ore) was then digeſted with muriatic acid, which diſſolved nearly half, leaving a reſidue which by ſubſequent fuſion with alkali was found to be ſilex, ſtill holding a minute portion of ſilver. The muriatic ſolution was evaporated, during which it depoſited a few ſmall cryſtals of muriat of ſilver, after which water was added, which ſeparated an abundant white oxyd, which was found by various trials to be antimony.

Oxyds and Carbonated Oxyds of Copper.

The pureſt native oxyd of copper is the red octohedral ore from Cornwall. This appears to conſiſt of nothing but copper and oxygen, but, according to Mr. Chenevix, [h] the copper here exiſts in a leſs ſtate of oxygenation than in any other known ore of this metal.

One hundred parts were totally diſſolved in nitric acid with copious effervеſcence of nitrous gas. The pure blue ſolution was evaporated to dryneſs, muriatic acid was added, and a ſecond time evaporated to expel the remaining nitric acid, and convert the ſalt to a muriat. This latter diluted with water gave up 88.5 of copper to a plate of iron immerſed. Hence it is found to conſiſt of 88.5 of copper and 11.5 of oxygen. The particulars of this analyſis will be further noticed when deſcribing the oxyds and muriat of copper.

The pure carbonated oxyds of copper conſiſt of carbonic acid, oxygen, copper and water. With almoſt any acid they effervеſce ſtrongly, and give out their carbonic acid.

Fontana was the firſt who clearly ſhewed the preſence of carbonic acid in theſe ores. By diſtilling malachite *per ſe* in a glaſs retort, and collecting the products, he obtained ſome pure water, and a large quantity of gas, which extinguiſhed a candle, precipitated lime-water, and by various teſts was found to be carbonic acid.

The Siberian malachite analyſed by Klaproth will furniſh another example of analyſis. A hundred grains calcined in a moderate red heat in a covered crucible loſt 29½, which therefore is the quantity of the carbonic acid and water. Another 100 grains were diſſolved in dilute ſulphuric acid, and loſt by effervеſcence 18

[f] Ph. Tranſ. vol. 91. [g] Eſſays, vol. 1. [h] Phil. Tranſ. for 1801.

grains, which, fubſtracted from the 29½, leaves 11.5 for the water. The ſulphuric ſolution decompoſed by metallic zinc gave 58 grains of copper. Another portion of the malachite was diſſolved in nitric acid, and the precipitate by ammonia was entirely rediſſolved by an exceſs of this alkali, ſhewing therefore the total abſence of iron. Laſtly, the quantity of oxygen united with the copper is inferred to be that which muſt be added to the 58 and 29½ to make up the 100, namely 12.5.

The native carbonat when pure has preciſely the ſame compoſition as the artificial, as Prouſt has clearly ſhewn, and will be preſently mentioned.

Arſeniat of Copper.

The compoſition of the different ſpecies of this family of copper ores as far as it is hitherto known is extremely ſimple, the ore when ſeparated from its matrix containing nothing but arſenic acid, oxyd of copper, water, and ſometimes a portion of iron. The arſenic acid is beſt eſtimated by uniting it by ſtronger affinity with ſome other metal where it makes an inſoluble ſalt of a known and invariable compoſition. Lead is the beſt fitted for this purpoſe, ſo that when the nitrat or acetite of lead is added to arſeniat of copper, a ſoluble nitrat or acetite of copper is formed, together with a white inſoluble precipitate of arſeniat of lead. By preliminary experiments Klaproth found that 100 grains of ſolid arſenical acid gave 297 grains of ſolid arſeniat of lead after moderate drying, and hence 100 grains of the arſeniat contain 33.66 of arſenic acid.[1]

For the analyſis, the ore being firſt diſſolved in nitric acid, the ſolution was accurately neutralized with carbonated potaſh, and then acetited lead was added till all precipitation ceaſed, a little of this ſalt remaining in exceſs. The precipitate of arſeniated lead when waſhed and dried indicated the proportion of arſenic acid in the ore. The ſolution now contained acetic and nitric acids, united with oxyd of copper and potaſh, and a little acetited lead; from which the lead was firſt ſeparated by ſulphat of ſoda, that precipitated it in the form of an inſoluble ſulphat, after which a little ſulphuric acid was added to engage the copper, and this metal in its turn was ſeparated by poliſhed iron in the uſual manner. The copper however is thus obtained in the metallic ſtate, but in the ore it is an oxyd, and therefore one-fourth of the weight of the copper muſt be added for oxygen, that is (as in the actual analyſis) for 40 parts of metallic copper, 50 of the oxyd of copper muſt be eſtimated. It is neceſſary to neutralize the nitrous ſolution at firſt, as the arſeniated lead is very ſoluble in acids, and therefore would not otherwiſe be properly collected.

Where iron is ſuſpected in the ore, the ſolution inſtead of being finally precipitated by poliſhed iron may be decompoſed by ammonia, and the copper ſeparated from the iron by an exceſs of the alkali.

As many acids form a white precipitate with the ſolutions of lead, the powder in queſtion is proved to be arſeniat of lead by digeſting with ſulphuric acid, which diſplaces the former acid, and leaves it uncombined in the liquor; and arſenic acid is detected by various methods mentioned under that article, particularly by giving a brick-red precipitate with nitrat of ſilver, the arſenic acid being firſt neutralized with ſoda.

Mr. Chenevix analyſes the arſeniats of copper in the ſame general way, but with ſome variations.

The ore (previouſly heated moderately to expel and eſtimate the mere water) is diſſolved in dilute nitric acid and nitrat of lead poured in. The ſolution (containing an exceſs of acid and therefore holding ſome of the arſeniated lead diſſolved) is then evaporated nearly to dryneſs, and alcohol added to compleat the ſeparation of the arſeniat of lead. After which the copper is decompoſed by potaſh, and is obtained in the ſtate of the brown oxyd.

Muriat of Copper.

The compoſition of this ſingular ore, found hitherto only in Peru, was aſcertained nearly at the ſame time by Prouſt, and by Rochfoucault, Beaumé, Fourcroy and Berthollet, a committee nominated for the purpoſe by the French Academy. The experiments are inſtructive.

The ore thrown on hot coals burns with a beautiful blue and green flame, whereas malachite, which it moſt reſembles in appearance, gives only a faint green flame. Diſtilled *per ſe*, malachite gives no other volatile product than carbonic acid and water; whereas the muriat gives in the ſame proceſs a quantity of oxygen gas with only a very ſmall proportion of carbonic acid, and a green liquor ſtrongly ſmelling of muriatic acid and proved to contain copper by giving a fine blue with ammonia. The reſidue in the retort was a brown oxyd of copper. This when expoſed to air turns green, ſhewing therefore that it is not a ſimple, but a muriated oxyd. Part of the muriat of copper therefore is volatilized, as it is well known that this ſalt readily

[1] Klaproth, vol. ii. 148.

riſes in diſtillation. The muriatic acid however is not ſufficient in this ore to ſaturate the oxyd of copper, and hence by ſimple boiling in water only a ſmall portion is diſſolved, which gives luna cornea with nitrat of ſilver.

This ore was analyzed by Klaproth in the following ſimple manner, its general contents having been aſcertained by the above-mentioned experiments. One hundred grains of the ore were diſſolved in nitric acid without heat, during which about 1½ of iron ochre was depoſited. It was then diluted and nitrat of ſilver added to aſcertain the quantity of lunea cornea. Of this laſt, 64½ grains were obtained, of which 10 grains were muriatic acid, according to ſeparate experiments by which it appears that 100 grains of ſilver form 133 of luna cornea, and of the 33 grains additional weight, 12.½ are oxygen, and 20½ muriatic acid. The copper was then precipitated as uſual by iron, and weighed 57½ grains in the metallic ſtate, equal to 73 of the brown oxyd. Klaproth does not conſider the iron however as eſſential to the ore, and therefore excludes it from the eſtimate.

Phoſphat of Copper.

This rare mineral was analyzed by Klaproth in the following way. It was firſt diſſolved in nitric acid, which made a clear blue ſolution, leaving untouched 16 parts out of 100, which were quartz. The ſolution was then juſt ſaturated with potaſh to engage any exceſs of nitric acid, and acetited lead was then added, which gave a copious white precipitate, and a ſmall exceſs of the acetite was uſed to enſure the compleat precipitation. This white inſoluble ſalt from appearance might be either ſulphat, or arſeniat, or muriat, or phoſphat of lead, but it was proved to be the latter by the two following teſts: 1ſt. when fuſed by the blowpipe, in the moment of cooling it aſſumed a garnet-like form with ſhining ſurfaces, which ſudden cryſtallization is peculiar to phoſphat of lead; and 2dly, when digeſted with dilute ſulphuric acid, ſulphat of lead was formed, and naked phoſphoric acid remained in the liquor, which being neutralized, partly by ſoda and partly by ammonia, gave the well-known microcoſmic ſalt. The native phoſphoric acid was therefore ſeparated from the copper in this analyſis, and from 100 grains (excluſive of the quartz) 138 grains of phoſphat of lead were formed, the phoſphoric acid of which was eſtimated from other experiments to amount to 30.95 grains. The cupreous ſolution was then treated with a little ſulphat of ſoda, to ſeparate the lead from the exceſs of the acetite remaining; ſome naked ſulphuric acid was then added, and the copper was ſeparated by iron in the metallic ſtate, which (increaſed in the proportion of 125 to 100), was found equal to 68.13 of oxyd of copper.

The above analyſes include almoſt all the important ores of copper, except thoſe in which it is combined with tin, which will be treated of under that metal. It may be mentioned however that the moſt accurate way of ſeparating copper from tin appears to be to immerſe in a ſolution of both metals a ſtick of tin, which will precipitate all the copper, whilſt the loſs of weight of the immerſed tin ſubtracted from the entire quantity of tin afterwards obtained from the ſolution, will indicate the quantity of tin belonging to the ore.

To proceed to the properties of pure copper.

Copper is a metal of a browniſh red colour, very ductile, malleable, and tenacious, ſo as readily to be flattened into thin plates, and to be drawn out into wire of great ſtrength comparatively to its thickneſs, more ſo (according to Count Sickingen) even than gold. It breaks with a hackly fracture. When rubbed, it emits a diſagreeable ſmell, and it gives a ſtyptic and nauſeous taſte. The ſpecific gravity of the pureſt Swediſh copper is 8.895[k], that of the better kinds met with in commerce but of leſs purity than the former, varies from this weight to about 8.6. The Japaneſe copper is found by Bergman to be 9.0.

Copper requires for fuſion what is commonly called a white heat, which is apparently not more, however, than is required to melt gold or ſilver. Before it melts, it ſhews on its ſurface changeable priſmatic colours. When in fuſion, or even at a heat ſomewhat below, if with acceſs of air, it begins to oxidate on the ſurface forming thin brown ſcales. Theſe may readily be knocked off when cold, and are then very brittle. This is an imperfect oxyd of copper, formerly called *copper aſhes*, *æs uſtum*, or *cinis æris*, and by repeatedly heating and cooling a bar of this metal, the whole may be thus changed. Theſe ſcales are found by Prouſt[l] to conſiſt of about 62 of the black or compleat oxyd, and 38 of copper nearly metallic. Dilute ſulphuric acid aſcertains this by diſſolving (when without heat) only the former part. By ſeparate calcination the whole is reducible into the black oxyd, which weighs one-fourth more than the copper from which it is procured. When intenſely heated the oxyd runs into a bright red-brown

[k] Hatchett. Phil. Tranſ. vol. 93. [l] An. Chim. tom. 32.

glaſs. At a heat ſomewhat above melting, a blue-green flame hovers on the oxidated ſurface of the metal, which is ſtill more viſible when the oxyd is thrown on the naked coals, and is moſt intenſely bright and beautiful when copper wire is burned by a ſtrong galvanic pile.

The ſame colour, with ſome variation of ſhade, is alſo produced by all the ſalts of copper when in contact with any burning combuſtible, thus they tinge the flame of alcohol very beautifully. The nitrat or muriat ſhews this to the beſt advantage. The flame of burning copper depoſits, though ſcantily, a fine greeniſh-grey oxyd, and hence it gradually collects as a kind of ſoot in the chimneys of copper-ſmelting houſes.

Copper ſoon ruſts in a damp air, and becomes covered with a fine green cruſt, which alſo contains carbonic acid. But this ſuperficial coating long preſerves the reſt of the metal beneath, and hence it is the work of a great length of time, and of circumſtances very unfavourable to preſervation, to corrode entirely a thick plate of this metal. Water projected on white-hot copper does not oxydate it, as it does iron, and no hydrogen is produced thereby.

Except in one or two rare combinations, copper appears to unite very uniformly with the ſame doſe of oxygen, forming (when free from water and every other ſubſtance) a browniſh-black oxyd, of which 20 per cent. or one-fifth, is oxygen, and the remainder is metal. This oxyd, as already mentioned in the analyſis of the ores, is invariably produced by boiling for a very ſhort time in potaſh any of the precipitates from the cupreous ſalts by any alkali, pure or carbonated, or the ammoniated ſolution of copper. The ſub-oxyd will be deſcribed with the muriat.

Copper or its oxyd is ſoluble in almoſt every acid with more or leſs eaſe. Many of theſe ſalts are of conſiderable importance.

Sulphuric acid acts upon copper only when concentrated and with the aſſiſtance of heat. For this purpoſe take copper-filings or clippings of thin ſheet copper, put them into a glaſs veſſel with about twice their weight of ſulphuric acid, and heat the mixture. As ſoon as ſolution begins, much ſulphureous acid gas is given out (which is a very convenient way of procuring this gas), and at laſt the whole is diſſolved into a dark coloured liquor, except a ſmall quantity of black reſidue, which is the ſulphuret contained more or leſs in all common copper. By dilution with water the liquor becomes of a fine blue.

This ſolution, by due evaporation and cooling, furniſhes cryſtals alſo of the ſame colour, and when regular (which they very ſeldom are) of a rhomboidal ſhape, forming the ſulphat of copper, or *blue* or *Roman Vitriol* of the ſhops.

Blue vitriol is alſo found native in abundance, partly cryſtallized, but generally diſſolved in the water of copper mines. Here it is produced by the decompoſition of the native copper pyrites in the ſame maner that the native ſulphat of *iron* ariſes from decompoſed iron pyrites.

Sulphuric acid diſſolves the oxyds of copper with eaſe even in the cold, and when diluted. The green carbonated oxyd is the moſt ſoluble in this acid.

Sulphat of copper has a very ſtrong ſtyptic, ſomewhat acid, and nauſeous taſte. It is ſoluble in about four times its weight of water. When dried at a moderate heat, not exceeding that of boiling water, this ſalt loſes, according to Prouſt, about 36 per cent. which is mere water, after which, the reſidue, which is a white powdery maſs, is equally again ſoluble and cryſtallizable. But if it is calcined with a ſtrong heat the acid itſelf is at laſt expelled, but without decompoſition, (being wholly ſulphuric and not in part ſulphureous acid, as in the calcination of ſulphat of iron) and a further loſs of 33 on the 100 of the cryſtallized ſalt takes place. The remainder after being kept ſome time in a low red heat to expel all the acid, is the perfect black oxyd of copper weighing 32 parts, one-fifth of which is oxygen and the remainder copper. Hence 100 parts of this ſalt, according to Prouſt, conſiſt of

Copper	25.6	forming	32.0
Oxygen	6.4	Black Oxyd	
Sulphuric Acid			32.
Water			36.
			100.0

Bergman alſo reckons 26 per cent of copper in this ſalt, but only 28 of water and 46 of acid.

Prouſt alſo deſcribes a *ſub-ſulphat* of copper, or with a leſs quantity of acid. To procure it, add potaſh to a ſolution of the common ſulphat, but not enough to precipitate the whole of the metallic oxyd. A *green* precipitate then appears, which is the ſub-ſulphat in queſtion. If ſaturated with the alkali the precipitate is *blue*, and is of a different nature, conſiſting of a ſingular compound of oxyd of copper with water, called by the ſame eminent chemiſt *hydrat of copper*, which will be preſently mentioned.

The ſub-ſulphat loſes by diſtillation only 14 per cent. of water. The reſidue boiled with cauſtic potaſh gives 68 of the black oxyd, whence its component parts are

Copper	54.4	68.0
Oxygen	13.6	
Water . .		14.
Sulphuric Acid		18.
		100.0

Sulphat of copper is of courſe decompoſed by all the alkalies pure or carbonated. If a ſolution of blue vitriol is poured into liquid potaſh, or if the latter is added to the former to compleat ſaturation, a *blue* precipitate falls down, which, when thoroughly waſhed with much boiling water, gives that peculiar combination firſt diſcovered by Prouſt, and called by him *Hydrat of Copper*.

This ſubſtance when dried at a heat not above that of boiling water, has not exactly the conſiſtence of a powder, but rather that of Pruſſian blue. With a heat ſomewhat higher it ſhrinks and gradually becomes converted to the black oxyd. By dry diſtillation it is found to loſe in its paſſage to the ſtate of black oxyd 24 per cent. of its weight, which is nothing but water, and about 1 of carbonic acid, which laſt it appears to abſorb from the air in drying, and 75 parts of the black oxyd remain. If this laſt is again moiſtened with water it does not return again to the ſtate of hydrat, nor aſſume any other but the browniſh black colour of the pure oxyd. Hence it appears that the hydrat is a true chemical combination of about 3 parts of oxyd of copper with one of water, and as Mr. Chenevix has well obſerved, enters as ſuch into the compoſition of the cupreous ſalts. Therefore ſulphat of copper (for example) might, with more propriety be ſaid to be thus compoſed.

Copper	25.6	forming	
Oxygen	6.4	Hydrat	42.6
Water	10.6	of Copper	
Sulphuric Acid .			32.0
Water of Cryſtallization			25.4
			100.0

The hydrat is ſtill better formed from the nitrat by the addition of potaſh, and alſo from all the other cupreous ſalts. In all caſes its water is ſeparated either by heat, or by *boiling* with potaſh.

Sulphat of copper is decompoſed by double affinity by many other ſalts. With common ſalt, muriat of copper is formed, and this is ſeen at once by the change of colour of the ſolution from blue to green. Sulphat of copper and acetite of lead produce the acetite of copper, and this is a convenient method of preparing this ſalt as will be further mentioned.

Copper unites readily with carbonic acid, and this combination, like the former, is alſo found largely in nature, the analyſis of which has already been noticed. Whenever copper is expoſed to a damp confined air it readily ruſts, and the green cruſt formed on its ſurface is alſo a carbonated oxyd. But the readieſt way of producing the carbonats artificially, is by adding a carbonated alkali to the ſulphat, nitrat, or any other acid ſalt of copper. A very copious bulky green precipitate is collected, which, well waſhed, and gently dried, forms a beautiful apple-green powder often uſed as a pigment in various forms. A hundred parts of copper diſſolved in any acid, and precipitated by carbonated potaſh or ſoda, produce invariably 180 of the green carbonat, dried at a boiling-water heat. This carbonat diſtilled without addition with a heat gradually increaſed to redneſs, gives out 10 parts of water, and 46 of carbonic acid, and at laſt 125 parts of the black oxyd remain in the retort, which quantity (as already mentioned) is preciſely that which is left when the green carbonat is boiled with potaſh, and is therefore alſo equal to 100 of metallic copper. To preſerve the uniform green colour, for which the carbonat is valued, it ſhould be repeatedly waſhed with boiling water, the heat appearing to increaſe the denſity of the precipitate, and of courſe the body of colour. An exceſs of the carbonated alkali rediſſolves part of the carbonated oxyd.

When the hydrat of copper is gently heated with a ſolution of carbonat of potaſh ſuperſaturated with carbonic acid, a part is diſſolved, forming a greeniſh-blue liquor[m], whilſt the reſidue remains at the bottom, of a colour approaching to that of the black oxyd. The ſolution, ſlowly evaporated, yields a ſingular ſalt, being a carbonat of potaſh, holding no more than 5 per cent of oxyd of copper, and 43 of carbonic acid. It is ſlightly deliqueſcent and cryſtallizable. A ſimilar ſalt, but with the baſis of ſoda, is formed, when carbonat of ſoda is uſed.

Copper diſſolves in nitric acid with extreme eaſe, when moderately diluted, and even in the cold. Much heat is excited, and if the ſolution goes on vigorouſly, a torrent of *Nitrous Gas* is given out (which indeed is one of the moſt convenient modes of procuring this gas) at the ſame time that the ſolution becomes of a deep blue.

[m] Chenevix.

The oxyds of copper diſſolve equally in nitric acid, but without the production of gas. When the ſolution is haſtily evaporated to a certain point, and ſuffered to cool, it congeals into a deep-blue ſaline maſs, which again rediſſolves ſpontaneouſly, if kept expoſed to air. A ſlow careful evaporation gives this ſalt in the form of ſix-ſided priſms, but very deliqueſcent and intenſely acrid. If this blue nitrat be evaporated beyond the point at which it would cryſtallize when cold, nitrous gas comes over, and a green ſcaly concretion begins to ſeparate from the thick blue liquor, and incruſts the inſide of the retort. If the diſtillation is here ſtopped, this green concrete may be ſeparated by water which diſſolves only the ſtill undecompoſed blue nitrat, and does not touch the other. Prouſt conſiders this green ſubſtance as a *ſub-nitrat* of copper, or having a deficiency of acid, to which it owes its inſolubility in water, hot or cold, and its peculiar properties. It is proved to be ſtill a nitrat, by giving out this acid when the ſulphuric is added. By thorough calcination all the acid and water are expelled, and the black oxyd of copper alone remains, which weighs exactly 125 parts when 100 of reguline copper have been uſed, and therefore is precifely ſimilar to the black oxyd left by boiling any cupreous ſolution with potaſh, ſo often mentioned. The ſame chemiſt gives the following proportions of the ſub-nitrat.

Black oxyd of copper	67
Nitric acid .	16
Water . .	17
	100.

The blue or perfect nitrat on the other hand contains only 27 per cent. of the black oxyd.

The nitrat of copper is very ſoluble in alcohol. This ſalt burns with a remarkably fine blue-green flame when thrown on burning charcoal.

The decompoſition of this nitrat by tin is ſo violent and rapid, as in certain circumſtances to produce actual combuſtion. This forms an amuſing experiment, firſt noticed by Dr. Higgins, and is thus performed. Spread out a piece of tin-foil the ſize of half a ſheet of paper, lay on the middle a ſmall heap of the ſolid blue nitrat, a little moiſtened, and over it a few filaments of tow, then double up the tin-foil round it on all ſides, twiſting it as tight as may be without breaking. In a very ſhort time it will feel burning hot, ſmall bubbles of the blue liquor will be ſeen oozing through the foil, and ſoon a copious ſtream of nitrous gas will ſhoot out from the different openings, attended with minute flaſhes of light and deflagration. A little ſprinkling of water will aſſiſt the effect.

A fine blue pigment is prepared from nitrat of copper, called *Verditer (Cendres Blues Fr.)* It is made in quantity, chiefly, if not entirely, by the refiners, who, after the proceſs of ſeparating gold from ſilver by aqua-fortis, recover the ſilver from its ſolution by means of copper, and thus leave a reſidue of nitrat of copper. This ſolution decompoſed by lime, the particular mode of which is kept a ſecret, made up into cakes, and dried gently, forms the beſt kind of verditer. The reſearch made into the nature of this valuable pigment by Pelletier,[a] is intereſting in a chemical point of view.

The analyſis of this pigment gave the following particulars: it was totally ſoluble in nitric and muriatic acids with much efferveſcence of carbonic acid: when diſtilled without addition, 600 grains loſt 200 grains, and gave 2 (French) pints of gas almoſt totally carbonic acid, together with a ſmall portion of water. The loſs on 100 grains is therefore 33⅓, of which the author of the experiment reckons 30 grains to be carbonic acid, and the remaining 3⅓ to be water. The calcined reſidue was a black ſubſtance, which was fuſed with a reducing flux, left a button of pure copper, and (making ſome allowance for the loſs by this mode of reduction) was eſtimated to amount to 50 per cent, of the original verditer. By the ſeparate treatment of another portion by ſulphuric acid, ſulphat of lime was produced, the earth of which amounted to 7 grains from 100 of the verditer. Conſequently there remains 9⅔ to compleat the 100, which is eſtimated to be oxygen. Pelletier therefore gives the following reſult from his analyſis.

	grains
Carbonic acid .	30.
Water .	3⅓
Lime .	7
Copper .	50
	90⅓
Remains for oxygen	9⅔
	100.

It is obvious however that there muſt be a great error in this eſtimation in the very ſmall quantity of water allowed, ſince it is ſhewn by Prouſt, and ſince by other chemiſts, that in all the blue or green ſalts of copper, a large quan-

[a] Memoires, tom. 2.

tity of water remains in their compoſitions, and is expelled, when by calcination the cupreous ſalt is converted to the black or brown oxyd as was the caſe in this inſtance. It is fortunate that the experimenter himſelf enables us to correct the error, (which is merely that of computation) without obliging us to impeach the accuracy of ſo excellent a chemiſt. From the *facts* given, therefore, we may ſafely correct the reſults in the following manner.

The button of copper actually obtained from the reſidue was in the proportion of 49 per cent. of the verditer, which (conſidering the unavoidable loſs by ſaline fluxes) may fairly be taken, with the author, at 50.

Fifty grains of copper require 12.5 of oxygen to be reduced to the ſtate of the black oxyd, which, as we have already ſeen, is the degree of oxygenation in which the metal exiſts in the nitrat. This again (according to Prouſt) would require 20.8 of water to bring it to the ſtate of hydrat. But it is alſo clear that the weight of carbonic acid is much over-rated through ſome ſingular overſight. The quantity actually obtained from 600 grains of verditer was about 2 French pints, the weight of which, according to Lavoiſier, would be only 66 French grains, and conſequently 100 grains would yield only 11 of this acid. The quantity of water was obviouſly only eſtimated at random. The corrected reſult therefore of Pelletier's experiments would be,

	grains	
Copper .	50.	83.3 Hydrat of Copper
Oxygen	12.5	
Water .	20.8	
Lime . .	7.	
Carbonic acid .	11.	
	101.3	

which correſponds very cloſely with the quantity analyzed. It may be added, however, that a very great difference in the proportion of ingredients is found in the different ſorts of verditer. The above analyſis is of the beſt ſort.

The ſame chemiſt's experiments on the compoſition of this curious colouring matter are equally intereſting. The preciſe difficulty appears to be to preſerve the blue colour, and prevent it from acquiring the ſhade of green, which properly belongs to the carbonats of copper. If nitrat of copper, or any other cupreous ſolution is precipitated by a carbonated fixed alkali, the colour is a deep apple-green. This, when rubbed with lime, aſſumes a fine blue at firſt, but by deſiccation it again returns to nearly its original green. It appears neceſſary, therefore, to uſe lime as the precipitant in the firſt inſtance, and not a carbonat, but here alſo M. Pelletier found by varied trials that the precipitate was at once blue when ſomewhat more lime was added than was neceſſary entirely to decompoſe the nitrat, but when the ingredients approached to mutual ſaturation, or eſpecially if the cupreous ſolution was in exceſs, the colour became green. This laſt however became blue by a freſh addition of lime, and in this method he propoſes to make the colour, as follows: add lime to a dilute nitrat of copper, juſt or hardly ſufficient to decompoſe the whole. This gives a greeniſh precipitate, which ſhould be well waſhed and nearly dried on a cloth ſtrainer. Then rub it with a freſh portion of lime, from 8 to 10 per cent. of its weight, which will immediately give it a fine and permanent blue, and dry it ſlowly. The preciſe quantity of lime and precipitate muſt be determined by experience, and by the ſhade of colour produced during the mixture, obſerving that lime will heighten the blue, and the green precipitate will ſoften it.

The Muriatic acid diſſolves copper with difficulty, except when concentrated and boiling, when hydrogen gas is given out; but its oxyds with much more eaſe, particularly the green watery oxyd. Thus if plates or ſhreds of copper be only moiſtened with muriatic acid, and expoſed to the air, the ſurface very ſpeedily becomes covered with a green muriated oxyd, which a freſh quantity of the acid of very moderate ſtrength will eaſily diſſolve; and by repeating the proceſs, a very ſtrong ſolution may be made. This ſolution, when hot, or very highly concentrated, is brown, but by dilution becomes graſs-green. By careful evaporation and cooling the ſalt cryſtallizes in rhomboidal priſmatic parallelipipeds, with ſome varieties,[o] or when more haſtily conducted, in feathery cryſtals. Theſe are commonly deliqueſcent, but when both the copper and the acid are free from iron they are permanent.[p] This ſalt is very ſoluble in water and alcohol. The latter takes up its own weight when boiling, and part ſeparates again in very perfect cryſtals. The compoſition of this cryſtallized ſalt is thus given by Prouſt[q].

Black oxyd of copper	40
Muriatic acid .	24
Water . .	36
	100.

[o] Pelletier, tom. 1. [p] Leonhardi. [q] An. de Chim. tom. 32.

The quantity of muriatic acid was determined by nitrat of silver. The watery solution of muriated copper, when sufficiently dilute, makes a kind of sympathetic ink, which is colourless in the cold, becomes yellow by warming, and again loses its colour on cooling.[r]

Chemistry is further indebted to the ingenious researches of Proust for the discovery of another species of muriat of copper, in which the metal appears to be less oxydated than in that already described, which makes a nearly colourless solution, and when solid is of a greyish-white. It is therefore termed for distinction the white muriat of copper, and was first noticed in investigating the remarkable disoxydating properties of the muriat of tin.[s]

Most of the salts of copper, and the muriat in particular, if combined with muriat of tin recently made, undergo a remarkable change. The latter salt, on account of its extreme attraction for oxygen, robs the cupreous salt of a portion, and reduces it to the state of a muriated oxyd which collects at the bottom of the vessel, and is white at first, but by exposure to light passes to the different shades of blue, violet and black. In this state it melts in the fire like luna cornea. This white muriat (or more properly *muriated sub-oxyd*), if heated with muriatic acid, dissolves therein, and crystallizes, by cooling, in tetahedrons. With nitric acid, some nitrous gas is given out, as with reguline copper and this acid, which shews that the sub-oxyd decomposes a portion of the acid in order again to saturate itself with oxygen. The solution is nitro-muriat of copper. Another remarkable character of this white muriat is, that when dissolved in ammonia it is not at first blue, as all the other ammoniated solutions of copper are, but quite colourless, as long as kept from the external air.

The white muriat formed as above mentioned by the solution of tin, when analyzed by solution in nitric acid, precipitation by nitrat of silver for the quantity of muriatic acid, and by an alkali for the metallic part, gave as follows.

Muriatic acid	24.75
Oxyd of tin	1.
Metallic copper	63.
Remains for oxygen	11.25
	100.0

Assuming this analysis as correct, it is obvious that the copper exists in a much lower state of oxygenation in this salt than in any hitherto mentioned, for in this, the oxyd of copper is composed of 63 of copper and 11.25 of oxygen, or (reduced to the hundred) of 84.84 of copper and 15.16 of oxygen: whereas the *Black oxyd*, to which all the common cupreous salts are reducible by loss of their acid and water, consists of 80 per cent. of copper and 20 of oxygen. The former therefore is properly distinguished as a *sub-oxyd*, and when combined with muriatic acid, as the white muriat, may be termed the *muriated sub-oxyd*.

The reader will now understand what takes place on distilling the common green muriat of copper without addition. The first effect is to expell merely any excess of acid and the water of crystallization, after which, by encreasing the heat, oxymuriatic acid comes over, (composed of the proper acid of the salt, and the quantity of oxygen which makes the difference between the perfect oxyd and the sub-oxyd) and a grey melted mass remains, which is chiefly the white muriat, or muriated sub-oxyd.

When this is exposed to the air for a day or two, it is again converted into the common green muriat. Part of the copper is itself volatilized, however, as is seen by the beautiful blue-green flame which the heated muriat gives to any burning matter.

There appears to be yet another state of combination of muriatic acid also noticed by Proust. It is the *sub-muriat of copper*, or a salt that differs from the common muriat, not by a lower degree of oxygenation of the metal, but in an inferior proportion of muriatic acid. It is produced by adding a little potash, (less than to saturation), to the green muriat. A green powder falls down, which is the sub-muriat, and corresponds with the sub-nitrat already described. If an excess of potash is added, the salt is entirely decomposed, and the precipitate is the *hydrat*.

This sub-muriat boiled with potash loses about 28 per cent. of its weight, and is reduced to the *Black oxyd*. A similar sub-muriat is said by the same chemist to be spontaneously deposited when copper is dissolved in nitro-muriatic acid, and its composition is given as follows:

Black oxyd of copper	79
Muriatic acid .	12.5
Water . .	8.5
	100.0

The green native muriat of copper of Peru

[r] Gren. [s] An. de Chim. tom. 28.

appears to be nearly in this ſtate. By heat it becomes brown, but regains its colour on expoſure to air.

Some experiments of Mr. Chenevix [t] throw further light on the nature of the ſub-oxyd and muriated ſub-oxyd above mentioned. It was noticed on the analyſis of the red octohedral copper ore that this ſubſtance was a pure oxyd, conſiſting of about 88.5 of metal and 11.5 of oxygen, and therefore in a much lower ſtate of oxygenation than in any hitherto obſerved. This ore on the affuſion of nitric acid diſſolved therein *with a rapid diſengagement of nitrous gas*, ſhewing thereby the neceſſity of a more compleat oxydation of the metal to enable it to unite with the remaining undecompoſed portion into common nitrat of copper. Muriatic acid was then tried, and was added to 100 parts of the ore. The liquor became hot and the ore diſſolved therein into a brown fluid, but which turned green on expoſure to air. Iron ſeparated 88 parts of metallic copper, leaving only 12 for the oxygen, which in the proportions of the common black oxyd, would only have indicated 48 of copper inſtead of 88; but as the whole 100 parts were diſſolved, it was proved that no part of the ore could have been a mixture of reguline copper and black oxyd, ſince reguline copper is not ſoluble in cold muriatic acid, and hence it appears a legitimate concluſion that the red octohedral ore is really a diſtinct and before unknown *ſub-oxyd* of copper. On adding water to the concentrated muriatic ſolution, a very copious white precipitate ſubſided, which became orange on further waſhing with water, and appeared to be the *muriated ſub-oxyd*.

A ſimilar muriated ſub-oxyd of copper Mr. Chenevix alſo produced artificially by mixing 57.5 parts of the black oxyd with 50 parts of the pulverulent regulus of copper obtained by precipitation by iron, and which may readily be reduced to a fine powder. This diſſolved almoſt entirely in cold muriatic acid, which is a curious circumſtance, ſince before the ſolution of the reguline part could have been effected, it muſt have taken a ſufficient portion of oxygen from the black oxyd; and thus (the one by taking and the other by loſing oxygen) both would be reduced to the ſtate of a ſub-oxyd, there being no more than 11.5 of oxygen in the black oxyd, which, by this diſtribution, proved ſufficient to render nearly 90 parts of copper ſoluble. It may be here remarked that a ſub-oxyd of iron is made in a ſimilar manner by mixing the perfect oxyd with iron filings and heating moderately, the reſult of which is the black *ſub-oxyd* or *ethiops* of iron.

Copper appears to have a ſtronger affinity for the muriatic acid than for the nitric or even the ſulphuric. Thus, according to Cornette, [u] if either the ſolid nitrat or ſulphat of copper be added to muriatic acid, a ſolution takes place with the production of cold, and if it is heated it immediately loſes the blue colour peculiar to theſe two ſalts, and acquires the green of the muriat. Alſo if the liquor is ſlowly evaporated muriat of copper is obtained in cryſtals.

The Acetous acid does not act upon reguline copper, but when oxydated it diſſolves it with eaſe into a fine green liquor readily cryſtallizable. There is alſo with this, as with many of the other cupreous ſalts, a diſtinct ſtate of *ſub-acid* and of ſaturated ſalt. Both the ſub-acetite and the acetite of copper are the products of a domeſtic manufacture carried on to a conſiderable extent in the South of France, and therefore require a fuller deſcription: the ſub-acetite being the common verdigris of the ſhops *(verdet)*, and the acetite, being the cryſtallized, or diſtilled verdigris, as it is called, *(cryſtaux de Venus—Verdet cryſtallizé.)*

This manufacture, in its preſent ſomewhat improved ſtate, is thus deſcribed by Chaptal [v] as carried on at Montpellier.

The materials for this manufacture are, 1ſt. Any refuſe matter of the ripe grape, the ſtalks, ſeeds, &c. but more particularly the *marc* or the cake that remains in the wine-preſs after the greater part of the juice has been extracted. This when fermented produces the acid requiſite to corrode the copper. 2d. Plates of copper of convenient ſize and previouſly hammered well to ſmooth the ſurface, in order that the corroded portion may be conveniently detached, without which preparation too much of the copper would peel off in ſcales, without being thoroughly penetrated by the acid.

The marc of the grape, which may be kept for a good while by being cloſe packed in caſks, is firſt fermented, ſimply by being laid looſely in a large barrel, moiſtened with water (or better with wine) and ſet in a warm airy place. After a while, ſometimes in a day, at other times in two or three weeks, it heats, ſwells, and gives a ſtrong ſmell of vinegar, and when the fermentation ſubſides it is fit for uſe. The richer the grape juice of courſe the better is the marc and the more perfect will be the ſubſequent fermentation, on which much of the quality of the verdigris depends. Hence it ſhould not be

[t] Ph. Trans. for 1801. [u] Mem. de l'Acad. for 1779. [v] Ann. Chim. tom. 25.

too clofely preffed, or, if poor, it fhould be moiftened with a little ordinary wine. To determine when the marc is fufficiently fermented, a fmall copper plate is buried in it for twenty-four hours, and if fit, the plate will come out covered uniformly with a green cruft. The plates are then all heated fcorching hot over a pan of charcoal, and laid regularly in earthen pots with a layer of the fermented marc at bottom and at top, and interpofed between each plate. The pot is then loofely ftopped with ftraw, and the whole left at reft from ten to twenty days. Thefe earthen pots (the fame in which the marc is fermented) are about 16 inches high, and 14 in diameter, and the mouth 12 inches. Each holds about 30 or 40 pounds of copper plate, with the requifite quantity of marc. When the plates are ufed for the firft time they are previoufly prepared by being rubbed with a rag dipped in a folution of verdigris in water, and fuffered to dry. Without this the firft produce of verdigris is apt to be black. This is not required a fecond time.

The earthen pots are emptied when the marc begins to whiten, and if the procefs has gone on well, the copper plates are found covered with a green cruft interfperfed with diftinct filky green cryftals. They are then taken out (the marc being thrown away) and fet on end face to face on wooden racks in a cellar; and when dry they are dipped in water (formerly in wine) and again fet to dry, and this is repeated once a week for fix or eight times which makes them fwell, and in every way improves and encreafes the crop of verdigris, which is finally fcraped off with a knife without difficulty. Every pot yields about five or fix pounds of rough verdigris, and the plates, after this is feparated, will ferve again repeatedly till they are corroded quite through.

The verdigris is fold by the maker in the rough ftate, and is further prepared by being well ground in wooden mortars and expofed to the air on fkins till fufficiently dry, in which procefs it lofes nearly half its weight. The whole of the manufacture of the rough verdigris is a part of houfehold bufinefs in the wine-farms about Montpellier, and is generally done by the women. It requires little attendance, and no other capital than the expence of the copper plates and earthen jars.

Verdigris thus prepared may be confidered as copper oxydated by the action of the acetous acid of the fermented materials, united with water, and a fmall portion of undecompofed acetous acid, together with part of the extractive or mucilaginous matter of the marc. Its exact compofition will be prefently mentioned. In this ftate it is infoluble, or nearly fo, in water. The colour is a fine green, and it is ufed more largely as a pigment than any other cupreous preparation.

Verdigris is however completely foluble in an additional portion of vinegar, and the refult is the perfect *acetite of copper*, a beautiful cryftallizable falt, fold at a very high price in the fhops under the name of *diftilled verdigris*. It is prepared from common verdigris in Holland and France, and Montpellier; the procefs which is followed at the latter place is very fimple, and is thus defcribed by the fame accurate obferver. Common vinegar is firft diftilled in a copper alembic, which feems to be a procefs conftantly going on in the fmall way in moft of the vintage farms in the neighbourhood. This is put with common verdigris into a copper boiler, and when a hot faturated folution is made, it is ftrained and let off to another copper evaporating veffel, where it is boiled down till a cruft of the falt appears on the furface. A light frame of fticks in crofs-bars is then funk in the liquor and the fire put out. On cooling, the acetite of copper crufts around the fticks in moft beautiful clufters of rhomboidal cryftals of a fine deep blue-green colour. When thefe are dried and finely powdered they form a green pigment of great beauty and value. It requires about three pounds of verdigris to make one pound of the cryftallized acetite. The part which remains undiffolved in the vinegar confifts of an imperfect oxyd or acetite which ufed to be thrown away, but, as Chaptal has obferved, when moiftened occafionally with vinegar, and expofed to the air, it yields a freth quantity of verdigris, and is then readily foluble in vinegar.

From the analyfis of feveral chemifts there appears to be very little uniformity in the proportion of the ingredients of the common verdigris, but according to Chaptal two kinds are particularly diftinguifhed in France, that of Montpellier, and that of Grenoble. The latter is prepared in a different manner from that already defcribed, no fermented refufe of the vintage being here ufed, but the procefs is chiefly to difpofe plates of copper in a proper room, and to moiften them repeatedly with diftilled vinegar till the furface is fufficiently oxydated and converted into verdigris.

In confequence of this difference in the pre-

paration, a certain difference is found in the appearance of the two kinds, that of Montpellier having a ſoft greaſy feel *, and ſhewing in its fracture a number of ſilky filaments like ſome kinds of malachite, and alſo being almoſt inſoluble in water. The other kind is dryer and harſher to the touch, of a deeper colour, breaking more like the cryſtallized ſalt, and more ſoluble in water. The former is ſomewhat cheaper and is preferred in painting, the latter is more uſed in dyeing. The analyſis of each by diſtillation *per ſe* with a graduated fire, ſlowly increaſed till every thing volatile was expelled, gave as follows.

A hundred parts of the verdigris of Grenoble gave

Carbonic acid - - -	9.10
Water weakly acidulous -	13.05
Strong, coloured acetous acid	53.95
Copper } left in the -	20.90
Charcoal } retort -	3.00
	100.00

A hundred parts of the verdigris from Montpellier gave

Carbonic acid - - -	8.00
Acetous acid very weak and very empyreumatic - }	65.15
Copper - - - - -	22.50
Charcoal - - - -	4.35
	100.00

In comparing theſe products it will be found that the difference may principally be explained from the different mode of manufacture. It may be premiſed that the products thus obtained by fire are by no means in the ſame ſtate of combination in which they exiſt in the ſalt: the heat decompoſing much of the acetous acid, (beſides what is ſimply expelled) and thence producing carbonic acid in abundance, and probably oxyd of carbon not noticed in this analyſis, whilſt the oxyd of copper is alſo decompoſed, the oxygen uniting with the new compounds, and the copper being left very nearly in the metallic ſtate, and mixed with a little charcoal from the vegetable matter. From the much leſs quantity of acetous acid, and the greater degree of empyreuma in the product of the Montpellier verdigris than in the other, it is reaſonably inferred to contain more extractive matter, and leſs acid in its natural ſtate, as might be expected, where an imperfectly fermented refuſe matter is uſed inſtead of pure acetous acid in the manufacture. The Montpellier kind therefore is a ſub-acetated oxyd of copper mixed with vegetable extractive matter: the Grenoble kind is almoſt pure ſub-acetite, and the part ſoluble in water is doubtleſs the perfect acetite.

The analyſes both of verdigris and of the acetite of copper as given by Prouſt, ſhew a very different proportion of ingredients in the ſub-acetite from that juſt mentioned. As the oxyd of copper is the only ſubſtance actually obtained in Prouſt's analyſis, the difference may be explained, partly by the different ſtate of dryneſs of the ſubſtance on which theſe two chemiſts operated, and partly by ſuppoſing that the one took the entire verdigris, and the other the pure ſub-acetite ſeparated from common verdigris by diffuſion in water. Prouſt obſerves, that when verdigris is put into cold water it gradually falls to pieces, near one-half is diſſolved (and hence the kind here examined more approaches that of Grenoble) and the remainder is a very fine green powder which diffuſes itſelf through the water, and ſubſides extremely ſlowly, together with the accidental impurities of the copper. This green powder appears to be the pureſt ſub-acetite of copper, and when waſhed and dried weighs about 42 per cent. of the original verdigris. When ſulphuric acid is poured on it pungent vapours of vinegar are given out. Boiled with potaſh, a black perfect oxyd of copper is obtained, in the proportion of 63 from 100 of the ſub-acetite. Diſtilled *per ſe* the products are the ſame in kind with thoſe of the acetite of copper (which will be preſently mentioned) and the reſidue is 52 per cent of copper almoſt in the metallic ſtate, but not entirely, ſince cold diluted ſulphuric acid is coloured blue by remaining in it, diſſolving the ſmall portion of oxyd of copper, and leaving the metallic part untouched. According to this analyſis therefore, 100 parts of the fine green ſub-acetite extracted from verdigris by diffuſion in water and dried, are compoſed of

Copper 50.4 } forming the black oxyd	63
Oxygen 12.6 }	
Remains for acid and water -	37
	100.

Acetite of copper (meaning the cryſtallized and perfectly ſaturated ſalt, or the *diſtilled verdigris*) may be produced, for experiment, ſimply by ſaturating diſtilled vinegar with oxyd of

* Jour. des Mines. No. 75.

copper, and cryſtallizing, but this will not readily afford a ſalt of that fine colour for which the acetite made from verdigris and diſtilled vinegar is ſo much valued. According to Prouſt 39 parts of the black oxyd produce with diſtilled vinegar 100 parts of the acetite; and on the other hand 100 parts of the ſalt decompoſed by boiling potaſh, give 39 or 40 of the black oxyd. Hence its compoſition is thus deduced.

Copper	31.2	making of black oxyd	39
Oxygen	7.8		
Acetous acid			61
			100.

The diſtillation of the acetite of copper furniſhes that pungent concentrated acid called *radical Vinegar*, the preparation of which is perfectly ſimple, and is deſcribed under the article Acetous *Acid*. In this caſe as in the diſtillation of common verdigris, the operation of the heat modifies, and conſiderably alters the arrangement of the component parts of this ſalt. Though by eſtimation it is reckoned to contain about 60 per cent. of acetous acid, no more than about 52 are obtainable by diſtillation, the remainder being changed by the heat, and by the oxygen of the copper (7.8 per cent.) and new products being formed probably by very complicated affinities. Theſe products are partly carbonic acid and carburetted hydrogen, and partly, as it appears, a portion of empyreumatic oil, which, towards the end of the proceſs, gives a peculiar ſmell and colour to the acid. A ſmall quantity of the acetite ſublimes as a white ſalt in the neck of the retort, or covering the upper part of the heated maſs, which appears to be the acetite, little, if at all altered, except by loſing ſome of its water of cryſtallization.[x]

After the diſtillation, a brown powder remains in the retort, which laſt is alſo ſometimes lined with a thin film of metallic copper. This brown powder is copper, almoſt metallic, but ſtill containing ſome oxygen, and alſo mixed with charcoal, according to M. Adet, in the following proportions in 90 parts, viz. Charcoal, 4.50; Copper, 78.66; and Oxygen, 6.84.

The entire products of the diſtillation of acetite of copper, as given by M. Adet, may here be inſerted as they appear conſiderably accurate. The undecompoſed portion of 288 parts of the ſalt was 25.5, deducting this, and reducing the remainder to the centeſimal proportion it will be as follows:

Acetous acid			53
Copper	30.	forming the reſidual brown powder	34.3
Charcoal & Oxygen	4.3		
Remains for gas given out			12.7
			100.0

The 30 parts of metallic copper (which were actually obtained by ſubſequent reduction,) are equivalent to 37.5 of black oxyd in the undecompoſed ſalt, a quantity not much differing from that given by Prouſt.

On account of the very high price of the diſtilled verdigris, many experiments have been made by chemiſts to produce an equally fine acetite of copper by a ſhorter method. Where the object is merely that of yielding radical vinegar by ſubſequent diſtillation, it is not difficult to combine acetous acid with any of the cupreous oxyds, or carbonated oxyds, and to produce a ſaturated acetite, with or without regular cryſtallization; but to form the beautiful blue-green ſalt for the painter or dyer is not ſo eaſy. The double decompoſition of acetited lead and ſulphat of copper, as mentioned under *Acetous Acid*, appears to ſucceed the beſt, the ſulphat of lead being entirely ſeparable by mere ſubſidence, and the green ſupernatant liquor affording by evaporation a very fine cryſtallized acetite of copper.

The natural combinations of copper with Arſenic and Arſenic acid have already been fully mentioned, together with the general mode of analyſis. With regard to the artificial arſeniats, Scheele[y] found that when arſenic acid was digeſted with copper filings a green ſolution was formed, and a blue arſeniat alſo precipitated. The ſulphat, nitrat, and muriat of copper undergo no apparent change by arſenic acid, but the acetite is decompoſed, and arſeniat is precipitated. But all the cupreous ſalts are decompoſed by double affinity, by arſeniated alkali of any kind; and a blue arſeniat of copper falls down. Mr. Chenevix alſo has the following experiments: Arſeniat of ammonia was added to nitrat of copper, which cauſed a double decompoſition, and arſeniat of copper fell down in blue cryſtalline grains. On evaporating the clear liquor and adding alcohol, another copious depoſition of cryſtals took place after a while, which were of a ſtill deeper blue and rhomboidal, and were alſo arſeniat of copper, and not nitrat of copper, this latter ſalt being ſoluble in

[x] Adet. An Chim. tom. 27. [y] Eſſays.

alcohol, and therefore not precipitable by it. Each of these arseniats was examined separately, first by calcination in a low red heat to expel the water, then by potash to obtain the black oxyd of copper, and lastly by nitrat of lead to estimate the arsenic acid. By this method the first arseniat was found to consist of

Oxyd of copper	50
Arsenic acid	27
Water .	22
	99

The second deeper-coloured arseniat consisted of

Oxyd of copper	35.
Arsenic acid	39.5
Water .	24.
	98.5

Arsenic, in the state of white oxyd when combined with oxyd of copper, forms a grass-green powder, first noticed by Scheele, and commonly called in chemistry *Scheele's Green*. It is formed by decomposing arseniated potash by sulphat of copper, by double affinity. The nitrat or any other salt will answer the same purpose. The inventor's process for making it in quantity is the following: Dissolve 24 ounces of sulphat of copper in water in a copper vessel over the fire; and, separately, in another copper vessel, 24 ounces of fine pearlash, and 11 oz. of white arsenic in water, also with heat, and strain each solution separately through linen; then add the arseniated potash, little by little, to the sulphat of copper, with constant stirring, which will immediately effervesce, and then will let fall a green powder. When the whole is mixed, let it stand some hours, edulcorate well with clear hot water and dry very gently in a warm room. From the above quantities 18½ ounces of the green powder are obtainable, which may be used as a pigment.

Phosphat of copper may be made artificially by adding phosphat of soda to nitrat of copper, or any other cupreous salt. A blueish-green sediment settles, which dries to a powdery mass mixed with crystals. A low red heat turns it brown and drives off all the water. It loses by this 15.5 of pure water. The residue is a phosphat of copper, consisting of 35 of phosphoric acid and 49.5 of oxyd of copper. *

A striking decomposition of nitrat of copper also takes place when a stick of fresh-melted phosphorus is immersed in this cupreous solution and exposed to light. By degrees the copper is precipitated in the metallic state on the phosphorus in crystalline grains.

The Prussic acid forms a red-brown salt with oxyd of copper. All the cupreous salts are decomposed by prussiat of potash or of lime, and the colour of the precipitate (which nearly resembles that of metallic copper without the lustre) is different from that of any other prussiat, and hence this may occasionally be used as a serviceable test. By drying, the colour changes to a dark chocolate hue.

Tincture of galls added to the cupreous solutions gives a dirty yellow precipitate.

All the other acids dissolve the oxyds of copper, forming salts little known and of small importance. In all of them, green in its various shades is the predominating colour.

Of the Alkalies, neither potash nor soda have any action on copper or its oxyds, except that (so often mentioned) of depriving the wet precipitated oxyds of their water of combination, by the help of a boiling heat, and bringing them to the state of the black oxyd, composed simply of about 80 per cent. of copper and 20 of oxygen.

The carbonated fixed alkalies however dissolve oxyd of copper by help of the carbonic acid, and by evaporation a triple salt of carbonic acid, alkali, and oxyd of copper may be obtained, as has been already mentioned.

Ammonia has no action on metallic copper, but dissolves its oxyds with ease. The usual colour of this solution is a most beautiful deep blue, and it is made in a variety of ways. The most direct way is to put together any oxyd or carbonated oxyd of copper and liquid ammonia in a phial, and digest them. The liquor becomes blue almost immediately, which colour deepens till the alkali is saturated. By slow evaporation carefully managed, the ammoniated copper may be got in fine blue silky crystals. Alcohol added when the solution is quite concentrated, much assists the crystallization. This salt loses its alkali by exposure to air, and at the same time absorbs carbonic acid, so that at last a green carbonat is left. Another method of making the ammoniated copper is to digest in a glass vessel lime, muriated ammonia, verdigris, and water. The lime first decomposes the muriated ammonia and disengages the alkali, which then dissolves the oxyd of copper, and very soon produces a fine blue liquor, consisting therefore of ammoniated copper and muriated lime. Lime water will answer as well, where only a weak

* Chenevix.

ſolution is wanted. The ſame materials will ſucceed without the verdigris, if made in a copper veſſel expoſed to the air. Both theſe ſolutions form the Aqua Sapphirina in pharmacy, uſed ſometimes as an external application in ſome ſurgical caſes. Another method of producing ammoniated copper immediately, is to ſuperſaturate with ammonia any of the ſalts of copper. Thus the firſt portion of this alkali added to muriated copper (for example) which is of a light green, ſeparates a green oxyd of copper; more of the alkali rediſſolves the oxyd, and the liquor now ſhews the fine blue, which indicates an ammoniated ſolution. In this way ammonia becomes a very excellent teſt for the preſence of copper, diſtinguiſhing it by the colour and the clear ſolution from every other metal except nickel.

Carbonat of ammonia will anſwer the ſame purpoſe as pure ammonia in the above proceſſes, the carbonic acid being moſtly expelled during the mutual action. This however is not neceſſary, ſince carbonat of ammonia, as ſuch, will alſo diſſolve oxyd of copper and retain it in a ſolid ſtate. A ſimple mixture, by trituration, of one part of ſolid ſulphat of copper and three parts of dry carbonat of ammonia efferveſces ſtrongly, and when carefully dried, forms a mixed blue ſalt, the *cuprum ammoniatum* of pharmacy.

A ſingular circumſtance takes place with ammoniated copper. If a bottle be filled full of liquid ammonia with a few clean copper filings, and kept cloſely corked, no ſolution enſues.[a] If the bottle be now opened for a while and then ſhut, part of the copper is diſſolved, but the liquor is ſtill colourleſs, till on again uncorking the phial, when it ſuddenly becomes blue at the top, and this colour ſpreads ſlowly down to the bottom. A freſh addition of copper filings, and again cloſing the veſſel, cauſes the blue colour again to vaniſh, but this is reſtored by the acceſs of air. To explain this fact an obſervation made by Prouſt may be added, which is, that the white muriated *ſub-oxyd* of copper (formed by the ſolution of tin and already deſcribed) when ſuperſaturated by ammonia in a cloſe veſſel, is indeed decompoſed by it, and an ammoniated ſolution is formed, but colourleſs, till expoſed to the action of air, when it becomes blue. It appears probable therefore that copper requires to be only ſlightly oxygenated to diſſolve in ammonia, but in this ſtate is colourleſs, and has a ſtrong attraction for that additional doſe of oxygen which is neceſſary to give the beautiful blue by which the common ammoniated ſolution is diſtinguiſhed. In the experiment above mentioned it is alſo probable that the copper filings added to the blue ſolution partly diſoxygenate and deprive it of colour, and themſelves are thereby in part diſſolved, unleſs the alkali be ſaturated.

Copper is in time oxydated and partially diſſolved by almoſt every ſaline ſubſtance, even thoſe that are perfectly neutralized, ſuch as common ſalt. This is proved by the fact that all copper veſſels long in contact with any ſaline matter and expoſed to air, become gradually covered with a green cruſt of oxyd. This is alſo obſervable in copper-bottomed ſhips, from which, when the old ſheathing is ripped off, a very large portion chips off in half-corroded ſcales. The decompoſition by muriated ammonia is very rapid, and a green muriated oxyd remains, which is ſaid to be the baſis of the *Brunſwick Green*.

When muriated ammonia and copper, or better, its oxyd, mixed dry are heated in a cloſe veſſel, the muriat, in ſubliming, carries up with it a portion of the metal (as it does with many, if not moſt other metals) and greeniſh-yellow flowers are collected, which conſiſt of muriated ammonia, with a ſmall and varying portion of oxyd of copper, generally about $\frac{1}{44}$. A part of the muriat is at the ſame time decompoſed and ammoniacal gas is given out.

Copper and ſulphur readily unite. When equal parts of copper filings and flowers of ſulphur are mixed and heated in a crucible much of the ſulphur burns off, but the remainder melts into a deep bluiſh-black maſs, which is an artificial ſulphuret of copper. According to Prouſt[b] 100 parts of copper take up in this way 28 of ſulphur, ſo that the ſulphuret is compoſed of about 79 of metallic copper and 21 of ſulphur. This combination contains no oxygen, and is therefore a ſimple *ſulphuret* of copper, and not a *ſulphuretted oxyd*. It is more fuſible than copper, readily melting at a red-heat. By roaſting in the open air, the ſulphur is expelled, and then an oxyd of copper remains, (as with the native ſulphurets) but the laſt portions of ſulphur adhere with great obſtinacy. Dr. Thompſon[c] alſo has found ſulphur and copper filings to unite by merely being mixed together in the cold, with or without water, and remaining long expoſed to the air.

Hydro-ſulphuretted water, or any of the liquid hydro-ſulphurets added to the ſolutions of copper produces a deep blueiſh-black pre-

[a] Gren. [b] An. Chim. tom. 38. p. 172. [c] Elem. of Chemiſtry.

cipitate, which is a hydro-ſulphuret of copper.

Phoſphorus unites with copper by fuſion, and forms a hard ſteel-grey brittle alloy. This combination was obſerved by Pelletier, in the preparation of phoſphorus in the great way. The phoſphoric acid from bones being commonly evaporated in a copper veſſel diſſolved a ſmall portion of the metal, and in the ſubſequent diſtillation of this vitreous phoſphoric acid with charcoal, ſeveral metallic globules were often found in the reſidue, ariſing from the reduced copper uniting with and keeping down a portion of the phoſphorus.

Phoſphuret of copper may be made according to Pelletier [c] in two ways: in one (imitating the accidental diſcovery) 8 parts of copper filings and 8 of vitreous phoſphoric acid are intimately mixed with 1 of charcoal powder, and then being put into a crucible and covered with a little more charcoal powder, are heated intenſely. In this proceſs, part of the reduced phoſphorus burns off, but the reſt combines with the copper forming a hard grey brittle alloy, capable of a high poliſh. In the other method which is ſimpler, copper filings are made red-hot in a crucible, and pieces of phoſphorus are carefully and repeatedly projected on the metal which immediately melts down into the ſame grey phoſphuret. A hundred parts of copper may be increaſed by this means to about 120, and in this ſtate the ſpecific gravity, according to Sage, [d] is 7.122. This phoſphuret, if kept in fuſion expoſed to the air, loſes gradually moſt of its phoſphorus, which burns with the bright flame and ſmell peculiar to this ſubſtance.

Phoſphuret of copper is more fuſible than copper. If kept in fuſion covered with charcoal powder, or under melted glaſs of any kind ſo as not to be expoſed to the action of air, it loſes all the exceſs of phoſphorus which it may contain, above that quantity which is equivalent to an increaſe of one twelfth of the weight of the copper, [e] after which it remains unaltered in any continuance of cloſe fire. This therefore ſeems to be a point of mutual ſaturation, and this phoſphuret is therefore compoſed of about 7.7 of phoſphorus and 92.3 of copper. This phoſphuret has the grain and colour of ſteel, takes a very high poliſh, and remains very long untarniſhed in the air, but is brittle. With a leſs proportion of phoſphorus it again becomes malleable and of a yellowiſh-white colour, ſo that it is poſſible that this may be found uſeful (with other additions) in producing a white alloy, which would be ſerviceable in manufactures.

The fixed oils when kept ſome time in contact with copper oxydate and diſſolve a portion, and thereby become green.

The alloys of copper are ſo numerous and important that they will be ſeparately deſcribed in the following article.

The uſes of copper, in all its various ſtates, are almoſt endleſs, and only, if at all, inferior in number to thoſe of iron. Beſides the variety of uſes for which copper and its alloys are employed in the metallic ſtate, various pigments and dyeing materials are obtained from its ſalts, and the oxyd is uſed to give an emerald green to coloured glaſſes and enamels.

All the ſalts of copper are more or leſs poiſonous, producing violent naufea, and the ſevereſt pain and inflammation of the alimentary canal. Yet from the ſudden vomiting which they excite, a large doſe may be given with ſafety, and this is ſometimes uſed when it is neceſſary immediately to empty the ſtomach. Copper is however very little uſed medicinally in any form.

The affinities of the oxyd of copper are given by chemical writers in the following order. [f] The gallic, oxalic, tartareous, muriatic, ſulphuric, nitric, arſenic, phoſphoric, ſuccinic, fluoric, citric, acetic, boracic, pruſſic, and carbonic acids; ammonia, and fixed oil.

COPPER, *Alloys of.*

The alloys of copper (that is, thoſe in which this metal predominates) are more numerous and more important in the arts than thoſe of any other metal. Many of them are perfectly well known, and have been in uſe from very antient times; of many the exact compoſition, and particularly the mode of preparing, are kept as ſecret as poſſible; for even when the preciſe compoſition of an alloy is found by chemical analyſis, it may often be extremely difficult to produce a mixture by common methods, which ſhall have exactly the ſame ſhade of colour, the ſame malleability, texture, ſuſceptibility of poliſh, or ſome other excellence, which, perhaps, a mere accident has diſcovered to the poſſeſſor. Another circumſtance of infinite conſequence to the manufacturer is the ordinary ſtate of purity of the materials he employs, and this alone will account for the great ſuperiority of one manufacture over another; thus the Swediſh copper is commonly purer than the Britiſh, and makes more malleable alloys, the Engliſh tin better than moſt of the foreign, and the like.

[d] Jour. de Phyſ. tom. 38, [e] G. B. Sage, Jour. Phys. [f] Grer.

The principal objects of alloying copper appears to be to render it less liable to tarnish, and especially to be acted on by common animal or vegetable substances, (which, when used for culinary purposes, is of extreme importance): to make it more fusible, and harder, and able to take a higher polish; and to alter its colour either to a golden yellow or a silvery white. All these objects are attainable by different alloys.

Copper with Gold, Silver, and Platina.

These are seldom if ever used in the proportions in which they would be alloys of copper, being much too costly for any purpose of manufacture, considering the great deterioration of the more valuable metals; with this exception, however, that a very small portion of silver much improves the composition of the alloy of copper and tin, when used as bell-metal or speculum-metal. This will be afterwards noticed. Copper is used largely as an alloy of gold and silver, and it is often plated with one or the other. This subject we shall refer to these metals respectively.

Copper with Arsenic.

Arsenic has beyond any other metal the effect of whitening copper, but as it is readily evaporated in fumes at less than a red heat, and therefore at a temperature much below the melting point of copper, some management is required to effect a combination of the two. For this purpose, first melt the copper in a crucible, then wrap up in paper some white arsenic mixed with a little charcoal, or else reguline arsenic, or even white arsenic alone, or, as some recommend, arsenic and potash, and with a long pair of tongs thrust it to the bottom of the melted copper. The arsenic immediately rises through the copper, and most of it burns off in dense white fumes, but a certain portion is retained. The mixture should be immediately cooled. It seems somewhat a more convenient way to put the arsenic in a small crucible, inverting it over the melted copper and forcing it down to the bottom, holding it there till all the arsenic has passed through.[g] By repeating this several times, the copper may probably be more fully saturated with arsenic, observing each time to give no more heat than requisite.

This alloy is quite white, of a very close texture, but perfectly brittle, and where the arsenic is sufficient entirely to destroy the yellow of the copper it is liable to tarnish in the air, the more in proportion to the dose of arsenic. As soon as it melts the arsenic begins to escape, and on account of the extreme volatility of this ingredient it is impossible to combine accurate proportions, so that always enough arsenic must be used, to allow for a considerable loss. When kept long in fusion, the copper regains its malleability in proportion as the arsenic escapes, but even when it has become quite malleable, the colour does not entirely return to the original copper-red, but long remains of a dingy yellow.

Vauquelin[h] has observed, that when equal parts of silver and copper are alloyed (which by themselves make a pale yellow mixture) the addition of so little as 2 of arsenic to 100 of the alloy gives a perfect whiteness, whilst the ductility and malleability remains. Beyond 5 per cent. of arsenic the alloy begins to be brittle, without increasing in whiteness.

Arsenic is used in small quantity in some of the more compound white alloys of copper, particularly in speculum-metal.

Copper with Manganese.

Attempts have been made to whiten copper and retain the malleability by alloying with manganese, but with little success. The combination is difficult, and seems to require two processes. First, let copper and oxyd of manganese with charcoal be mixed, and put into a crucible lined with charcoal, and heated very intensely. This gives a black, crumbly, granular, semi-metallic mass, consisting of the metals partly combined, and of some of the charcoal. The whole of this again fused under borax, gives a metallic button of a dirty yellowish white, hard, and somewhat malleable.[i]

If the combination is attempted by a single process and a flux used, the manganese and flux will melt together, and will corrode the crucible long before any reduction can take place.

Copper with Iron.

These only unite when the iron is in small quantity. The alloy is grey, hard, and somewhat brittle.

Tutenag is a white alloy of copper, zinc, and iron, according to Keir,[k] which is very hard, tough, and sufficiently ductile to be wrought into various articles of furniture, such as candlesticks, &c. which take a high polish, and when made of the better sort of tutenag are hardly distinguishable from silver. The inferior kinds are still white, but with a brassy yellow.

The Chinese *Petong* is another fine, white, malleable alloy of copper, the composition of which is not exactly known, but it contains a

[g] Jour. Phys. tom. 1. [h] An. Ch tom. 39. [i] Gmelin in Comment. Gotting. vol. 9. and own Experiments.
[k] Notes to Macquer.

ſmall portion of ſilver. Neither of the above metals are imitable by the common proceſſes.

According to Dizé,[l] when the iron forms only $\frac{1}{16}$ of the maſs it is ſtill magnetical, but not ſo when it is only about $\frac{1}{10}$. Iron does not whiten copper ſo much, in equal quantities, as tin does, and ſtill leſs than arſenic.

Copper with Lead.

Theſe metals unite to appearance very intimately by fuſion, but, what is very remarkable, when a maſs of this alloy is expoſed to a heat leſs than that at which the whole melts, the lead alone ſweats out, leaving almoſt all the copper in a porous or honeycombed ſtate. When the copper holds a ſmall portion of ſilver, the lead carries the latter out with it, and this is the principle of the old proceſs of *eliquation*, formerly much uſed in the extracting of SILVER from copper ores. Copper with about a fourth of its weight of lead forms *pot-metal*.[m] The antient Roman pot-metal, according to Pliny, was compoſed of 100 of copper, 2 of lead, and 2 of tin. The ſame ingredients, but with more of the two latter, were the materials of many of the ancient Greek and Sicilian coins.[n]

Copper with Zinc.

Copper nearly ſaturated with zinc, that is, in which the latter makes about a fourth (more or leſs) of the mixture, forms *braſs*, the moſt important of all the alloys of this metal, and which has been fully deſcribed under that article. With a much leſs proportion of zinc the colour of the alloy approaches very nearly to that of gold, and the malleability increaſes. Mixtures chiefly of theſe two metals are uſed to form a variety of yellow or gold-coloured alloys, known by the names of *Tombac*, *Manheim or Dutch Gold*, *Tinſel*, *Similor*, *Prince Rupert's Metal*, *Pinchbeck*, &c. but the preciſe compoſition varies according to the fancy or the experience of different manufacturers. The Dutch gold may be beaten out into extremely fine leaves, which, when freſh, have nearly the brilliance of gold-leaf, and are uſed as a cheap imitation of it, but they tarniſh very ſoon. The mixture may be made either by directly melting copper and zinc, or by mixing braſs and copper. In either caſe the copper ſhould be melted firſt, and the zinc added afterwards, the whole ſtirred together with wood, covering it with a little charcoal, and poured out immediately, to prevent the loſs by the burning off of the zinc.

Several direct experiments on the union of copper and zinc in different proportions were made by Margraaf.[o] In all, the copper was the pureſt Japaneſe, and the mixture was made in the way above mentioned. With 8 drams of copper and as much zinc, much of the latter unavoidably burnt off and the alloy only weighed 12 inſtead of 16 drams, the mixture was hard, brittle, yellow, and of a radiated texture. With 16 drams of copper and 8 of zinc, the loſs by burning was only $\frac{1}{2}$ of a dram. The alloy was ſofter than the laſt, ſtill radiated, yellow, and began to be a little malleable. From this, ſucceſſively diminiſhing the proportions of zinc, the alloy became ſofter, more malleable, and of a colour more and more approaching to gold: and at laſt, with 11 or 12 of copper and 1 of zinc, the fineſt golden tombac was produced. According to Wiegleb[p] the Manheim gold is made by melting ſeparately 3 parts of copper and 1 of zinc, mixing them, covering with charcoal, ſtirring with a ſtick and cooling immediately. Theſe proportions ſcarcely differ from thoſe of ſome kinds of braſs. Beaumé gives for the ſame metal 4 of copper and 1 of zinc, whence it is obvious that the proportions are quite arbitrary, but it appears that the alloy is not made, as braſs is, by cementation, but by ſimple mixture of the metals. A very ſmall quantity of tin is ſometimes employed, but this metal has the diſadvantage of remarkably diminiſhing the malleability of copper and its alloys. A fine malleable tombac is made, however, with 16 of copper, 1 of zinc, and 1 of tin. An alloy of 12 of braſs and 1 of tin is ſcarcely malleable.

A kind of tombac is the material of which a large proportion of the Roman coins was compoſed. Klaproth[q] on analyzing ſeveral, ſtruck during the firſt century of the emperors, found them all to conſiſt either of pure copper, or of copper and zinc, in which the latter metal made generally from a fifth to a ſixth of the maſs. A little tin and lead were found in ſome, but in ſuch ſmall proportion as to appear only an accidental impurity.

Copper with Tin.

The alloys of copper and tin are extremely important in the arts, and curious as chemical mixtures. They form in different proportions mixtures which have a diſtinct and appropriate uſe. Tin added to copper makes it more fuſible, much leſs liable to ruſt or corroſion by common ſubſtances, harder, denſer, and more ſonorous. In theſe reſpects the alloy has a real advantage over unmixed copper, but this is in

[l] Jour. Phyſ. tom. 36. [m] Watſon's Eſſays, vol. 4. [n] Leonhardi Worterbuch. [o] Klaproth. [p] Mem Acad. Berlin, 1774. [q] Phil. Mag. vol. 17.

many cafes more than counterbalanced by the extreme brittlenefs, which even a moderate portion of tin imparts, and which is a fingular circumftance confidering how very malleable both metals are before mixture, and the remarkable foftnefs and ductility of tin.

The fenfible qualities of the different mixtures are the following. Copper alloyed with from 1 to about 5 per cent. of tin is much harder than before, the colour yellow with a caft of red, and the fracture granular. It is ftill confiderably malleable. This appears to be the ufual compofition of many of the very antient copper tools and weapons before the common ufe of iron;[r] whence it appears that the ancients did not (as has often been fuppofed) poffefs any peculiar art of hardening pure copper, otherwife than by mixture. It is certain that the quenching of red hot copper in water will not at all make it harder, or have any fuch effect as it has upon iron. An alloy in which the tin is from $\frac{1}{16}$ to $\frac{1}{8}$ of the whole is hard, brittle, but ftill a little malleable, clofe-grained, and yellowifh-white. Where the tin is as much as $\frac{1}{5}$ of the mafs, it is now entirely brittle, and continues fo in every higher proportion. The yellownefs is not entirely loft till the tin is above $\frac{2}{3}$ds of the whole.

Copper, or fometimes copper with a little zinc, alloyed with as much tin as will make from about $\frac{1}{16}$ to about $\frac{1}{5}$ of the whole, forms an alloy which is the principal, and often the only compofition for bells, brafs cannon (fo called) bronze ftatues, and feveral fmaller purpofes, and hence it is called *Bronze*, or *Bell-Metal* (always obferving that there is no perfect uniformity in the different alloys under thefe names, either in the proportion or the actual number of ingredients) and it is excellently fitted for thefe purpofes, by its hardnefs, denfity, fonorouſnefs, and fufibility, whereby the minute parts of hollow moulds may be readily filled before it fixes in cooling. For cannon, a lower portion of tin feems to be ufed. According to Dr. Watfon,[s] the metal ufed at Woolwich is 100 parts of copper and 8 to 12 of tin. Hence it ftill retains fome little malleability, and of courfe is tougher than with more tin. Bronze cannon are much lefs liable to ruft than thofe of iron, but in large pieces of ordnance, by very rapid firing the touch-hole is apt to melt down and fpoil the piece; of which there is a remarkable inftance at the Tower of London of a mortar of the largeft calibre thus fpoilt at the fiege of Namur. On account of the fonorouſnefs of bronze, thefe cannon give a much fharper report than thofe of iron, which for a time impairs the hearing of the people that work them. A common alloy for bell-metal is about 80 of copper to 20 of tin; or where copper, brafs, and tin are ufed, the copper is from 70 to 80 per cent. including the portion contained in the brafs, and the remainder is tin, and zinc. The zinc certainly makes it more fonorous. Antimony is alfo often found in fmall quantity in bell-metal. Some of the finer kinds ufed for fmall articles contain alfo a little filver, which much improves the found.

When the tin is nearly one-third of the alloy it is then moft beautifully white, with a luftre almoft like that of mercury, extremely hard, very clofe-grained, and perfectly brittle. In this ftate it takes a moft beautiful polifh, and is admirably fitted for the reflexion of light for all optical purpofes. It is then called *fpeculum metal*, which however, for the extreme perfection required in modern aftronomical inftruments, is better mixed with a very fmall proportion of other metals particularly arfenic, brafs, and filver. But the bafis of thefe compofitions is copper alloyed with nearly half its weight of tin. The ufe of this alloy for the fame purpofe is of great antiquity, and certainly was in frequent ufe in the time of Pliny. Klaproth analyzed a portion of an antient fpeculum in the following manner. The fragment was compact, very hard, and brittle, the freſh fracture greyifh white, which by polifhing acquired a beautiful luftre. A hundred grains were heated with nitric acid, whereby a blue folution was made, and a part remained undiffolved. The folution being firft tried without effect with muriat of foda for filver, was mixed with a folution of fulphat of foda, which gave a white precipitate of fulphat of lead, equivalent to 6 grains of lead. The copper was then feparated by iron, and amounted to 62 grains. The undiffolved portion flowly digefted with muriatic acid, gave a ftraw-yellow folution, which, decompofed by zinc, gave 32 grs. of metallic tin. This fpeculum therefore confifted of 62 parts of copper, 32 of tin and 8 of lead, which laft was probably an adulteration of the tin and not added defignedly.

When more tin is added than amounts to half the weight of the copper, the alloy begins to lofe that fplendid whitenefs for which it is fo valuable as a mirror, and becomes more of a blue-grey. As the tin increafes, the texture becomes rough-grained, and, as it were, rotten,

[r] Dizé. Jour. Phyf. p. 36. [s] Eſſays.

and totally unfit for manufacture. The ſpeculum metal is therefore in the higheſt proportion of alloy of tin that copper will admit for any uſeful purpoſe.

A perfect ſpeculum-metal ſhould be quite white without ſhewing any caſt of yellow when poliſhed, not very liable to tarniſh, quite free from pores even when examined by a lens, of a certain coherence or toughneſs to bear the grinder, and for the convenience of working, as ſoft as may be conſiſtent with the other requiſites.

Mr. Mudge, whoſe ſpecula were celebrated for their goodneſs, obſerves, that the extreme of whiteneſs is given by 32 parts of copper and 16 of tin,[t] but this is exceſſively hard and brittle; that 32 of copper with 14½ of tin is ſtill quite white and as hard as can be wrought. He alſo obſerved by many trials, that the metal to turn out free from pores ſhould be twice fuſed, that is, the firſt time for the purpoſe of mixture (in which the copper is to be firſt melted ſeparately) and then remelted with as little heat as poſſible, for caſting. As there is always ſome loſs by the calcination, chiefly of the tin, a little allowance in the proportion of this latter may be made on account of the double fuſion.

The moſt elaborate mixture and accurate directions on this important ſubject are given by Mr. Edwards, whoſe ſpecula are of extreme excellence, and are publiſhed in the nautical almanac for 1787,[u] of which the following are the leading particulars.

The quality of the copper ſhould firſt be tried by adding ſucceſſively from ſo much ſhort of half its weight of tin that it proves a little yellow, to the full half of tin, and by compariſon aſcertaining the maximum of whiteneſs, obſerving that beyond this point the alloy begins to loſe part of the brilliance of fracture and to become bluiſh. When this is found, take 32 parts of the copper, melt it, add one part of braſs and as much ſilver, with a little black flux to cover the ſurface; when theſe are melted, ſtir with a wooden rod, and pour in from 15 to 16 parts of tin (according as found neceſſary by previous experiment) fuſed in a ſeparate crucible with a low heat, ſtir the mixture again, and immediately pour it into cold water. Then in the ſecond melting (with as little heat as will ſuffice) take for every 16 parts of the compoſition 1 part of white arſenic, wrap it in paper, thruſt it to the bottom of the fluid metal, and ſtir with a wooden rod till no more arſenical fumes eſcape, immediately after which caſt the metal in a ſand-mould. Then while it is ſtill red-hot lay it in a pot full of very hot embers and cool it very ſlowly: unleſs this precaution is particularly obſerved, the metal will fly in pieces when cold, ſometimes even long after all ſuch danger is thought to be paſt; or it will ſplit in the poliſhing. For the particular manner of conſtructing the mould, and the whole of the nice and laborious operations of grinding and poliſhing to a perfectly true figure, the reader is referred to the two papers above mentioned.

Both the braſs, and the ſilver, and the arſenic appear to have their diſtinct uſe. The braſs makes the mixture tougher and not ſo exceſſively hard and brittle. The ſilver improves both the texture and colour, but is not an eſſential though really an uſeful addition. The arſenic is found by actual compariſon to make the metal finer, and particularly cloſer in texture, and therefore leſs liable to be porous. It ſenſibly increaſes the ſpecific gravity, which, before the arſenic is added, is 8.78, but afterwards, 8.89. It is added in the ſecond melting, that as little as poſſible may be diſſipated in vapour. A greater proportion would make the metal liable to tarniſh. An alloy containing 6 of copper, 2 of tin, and 1 of arſenic, is nearly the proportion of Sir I. Newton's ſpecula, which is very good, but poliſhes ſomewhat yellow.

The ſeparation of copper from bell-metal and all the tin alloys in the large way, happened to be an object of conſiderable importance in France in the midſt of the revolutionary war, when the importation of copper was nearly impracticable, and a large quantity of it was required for general purpoſes, and particularly for the coinage. A number of very ingenious experiments were then made on the beſt method of freeing the metal of church bells from their tin and other alloy, and obtaining thence a good malleable copper with the leaſt poſſible expence or loſs.

The circumſtances in which it is worth while to melt down great bells for the ſake of the pure copper do not often occur, but the various proceſſes may be here ſhortly noticed as important to the hiſtory of the chemical properties of copper alloys, and as a very happy example of the application of theoretic chemiſtry to the purpoſes of manufacture. Pelletier[x] and Fourcroy[y] ſeem to have chiefly diſtinguiſhed themſelves in this reſearch, and each chemiſt appears to have followed nearly the ſame track, but with an acknowledged priority in the former.

[t] Phil. Tranſ. vol. 67. [u] or Nicholſon's Journal, 4to, vol. 3. [x] Memoires, tom. 1 & 2. [y] An. Chim. tom. 9.

The great principle on which all the modes of purifying bell-metal depend, is the much more ready oxidability of tin by the united action of heat and oxygen, than copper. Hence even when bell-metal is ſimply kept melted in an open veſſel, a degree of ſeparation of the two metals begins inſtantly, the tin oxidating much faſter and ſooner than the copper, and of courſe the proportion of copper being therefore conſtantly increaſing in the fluid metal below.

Another equally important circumſtance alſo depending on the much ſtronger affinity of tin for oxygen is, that when oxyd of copper is mixed with tin at its loweſt ſtate of oxygenation, the tin ſtill retains its ſuperior affinity for oxygen, and deprives the oxyd of copper of this principle, and the products are, tin highly oxygenated and in a paſty ſemi-fluid maſs, and copper in the reguline ſtate, partly collected at the bottom of the veſſel and partly in ſmall globules entangled in the oxyd of tin.

The direct experiments of Fourcroy on this point are valuable.

A bell-metal was firſt made with 80 parts of copper and 20 of tin, both pure.

Of this alloy 100 parts were put on a muffle and expoſed for a certain time to a red heat, with acceſs of air. The whole was converted to a grey oxyd and weighed 104 parts. It was then heated ſtrongly for half an hour, and yielded a button of pure copper weighing 54 parts. Conſequently 26 parts of copper remained unreduced and mixed with the ſcoriæ of the oxyd of tin.

A hundred parts were calcined as above till they increaſed to 117. This being ſtrongly heated for half an hour gave a brown maſs, from which no copper ſeparated, except a few interſperſed globules. This therefore was too much oxygenated, that is, the tin had combined with ſo much oxygen in the firſt operation that it could not afterwards ſeparate any from the oxyd of copper.

A hundred parts were treated in the ſame way till they increaſed to 112. This melted into a brown maſs containing more globules of copper than the laſt, but ſtill the greater part remained unreduced.

Hence it appears that even an increaſe of 12 on 100 is too much, and by other experiments, the above chemiſt fixes the proper point of oxidation at which oxyd of copper is reducible by oxyd of tin to be from 5 to 7 on 100 of common bell-metal. However, when too highly oxygenated metal is mixed with the requiſite proportion of freſh metal, the former ſerves as a reducing flux to the latter, and the whole may then be made to yield a large portion of purified copper. This very ingenious plan has been found to anſwer extremely well in experiments made in the large way, as will preſently be mentioned.

Several ſubſtances have been tried that might aſſiſt in the firſt oxygenation of the bell-metal and ſhorten the proceſs. Of theſe, nitre and oxyd of manganeſe anſwer the moſt completely. For experiment in the ſmall way, 100 parts of bell-metal were powdered and mixed with about 14 of nitre, and heated, at firſt ſlowly, afterwards ſtrongly, and gave from 57 to 63 parts of copper, very malleable, but not quite pure. With a larger quantity of nitre the copper is purer, but more is loſt in the ſcoriæ.

A hundred parts of bell-metal mixed with 25 parts of oxyd of manganeſe, covered with broken glaſs, and ſtrongly heated for an hour, gave 36 parts of very good copper. It is of ſome importance to add glaſs or ſome other ſaline flux, as this brings the whole into thorough fuſion, and allows the copper to ſubſide through the vitrified oxyd of manganeſe. Where this is not done (and in the large way it would add to the expenſe) much of the copper is entangled in the vitrified manganeſe, and a ſubſequent operation is required to ſeparate it.

In the proceſſes of two other chemiſts, ſalt and ſand have each been found uſeful additions in the refining of bell-metal.

We may add the detail of two trials made in the large way by [a] Pelletier and Darcet by order of the French government, the one in which a portion was firſt oxydated, and this uſed as a reducing flux for the remainder, without any foreign addition whatſoever: and the other in which the refining was aſſiſted by oxyd of manganeſe. It may be premiſed that the manipulation of large quantities is not the ſame as with ſmall, particularly in the caſe of reduction to groſs powder, which may be eaſily done in an iron mortar on a few ounces or pounds, but not with any economy on large weights. Large maſſes therefore are firſt heated red-hot, when they may be eaſily broken up and ſpread about by an iron bar, and this is the way conſtantly practiſed.

The firſt proceſs was that of refining without addition. For this purpoſe 400 pounds of metal were put on a furnace, and when red-hot broken up with an iron bar, and ſpread about with conſtant ſtirring till the whole was con-

[a] Memoires de Pelletier, tom. 2,

verted into a reddiſh oxyd, ſomewhat cohering, and ſhewing the appearance of copper approaching to reduction. The 400 lbs. were increaſed hereby to 425 lbs. 2 ounces, making an increaſe of above 6¼ on 100.

Next, 800 lbs. of freſh metal were melted on a reverberatory, and the 425 lbs. 2 ounces of oxyd were added to it with conſtant ſtirring for about 20 minutes. The fire was continued for nine hours with occaſional ſtirring of the metal, and ſamples were drawn from time to time, which ſhewed a gradual approach in the melted metal to the ſtate of pure copper. As the refining took place at the ſurface of the fluid metal, or the point of contact between it and the ſcoria, the metal was there purer than at the bottom. Nine hours after the melting of the metal the copper beneath the ſcoria was fine, red, and fibrous, and was then run off into moulds. The ſcoria remained in for half an hour longer to melt out part of the metal entangled in it, which was then let out, and laſtly, the ſcoria itſelf was raked out, which was a black and paſty maſs that hardened exceſſively when cold, and ſtill contained ſome copper entangled in its ſubſtance. The reſults of this operation were 761 lbs. 12 ounces of copper run into the moulds; 46 lbs. of copper ſweated out of the ſcoria, and 7 lbs. 4 ounces of ſmall-grained copper, ſamples, &c. or in total 915 lbs. of copper from 1200 of metal, or nearly 68 from 100. The ſcoria weighed 474 lbs. and when thoroughly bruiſed in a ſtamping mill, and waſhed, it gave 18 lbs. more of copper.

Thus then by this ſimple proceſs nearly 70 parts (in all) of very good copper may be got from 100 parts of metal. whoſe known contents of copper are about 80 per cent.

The ſecond proceſs was that with the aſſiſtance of black oxyd of manganeſe.

In the ſame furnace 800 lbs. of bell-metal were firſt melted, and kept very hot, after which 25 lbs. of oxyd of manganeſe were thrown in, and the whole ſtirred and mixed with great care. Two hours after, 15 lbs. more of the manganeſe were ſtirred in, and the metal even then was ſenſibly purer than at firſt. This alternate addition of manganeſe, and ſtirring, continued till 100 lbs. of manganeſe were uſed, during which the metal conſtantly kept refining. Ten hours after the firſt melting, the copper was found to be ſoft, fibrous, and good, and was run off into moulds. It weighed 520 lbs. The ſcoria was ſofter than the former, and not ſo well melted. It weighed 344 lbs. and was ſtill viſibly rich in copper, as was proved by after waſhing. The copper, excluſive of that in the ſcoria, here amounted to about 60 from 100 of bell-metal.

From theſe and many other experiments it appears that by very ſimple means from ſix to ſeven eighths of the copper actually contained in bell-metal may be extracted; and in particular circumſtances this may be practiſed to advantage, but on the other hand the tin is loſt to moſt economical uſes, as its reduction from the ſtate of an impure ſemi-vitrified ſcoria is extremely difficult and expenſive.

COPPERAS is a kind of generic term ſynonimous with *Vitriol*, and applied in commerce and manufacture, with the diſtinction of *blue*, *green* and *white*, to the metallic ſalts the ſulphats of *copper*, *iron*, and *zinc*.

CORAL. This beautiful ſubſtance formerly much employed in medicine, is now (in this country at leaſt) entirely reſerved for ornamental purpoſes. Chemical analyſis ſhews it to be compoſed almoſt entirely of carbonat of lime organized by means of a portion of animal membrane. See SHELL and BONE.

CORK. *Kork*, Germ. *Liege*, Fr.

Cork is the bark of an evergreen oak (Quercus ſuber *Linn.)* that grows in the ſouthern parts of Europe, and on the ſhores of the Mediterranean: it is ſtripped off every three years in large maſſes from two to three inches in thickneſs, and of a ſomewhat curved figure correſponding with that of the trunk of the tree. The only preparation which cork undergoes is that of being flattened; for this purpoſe it is ſcorched on both ſides to ſoften it, and in this ſtate is laid between flat heavy planks till it is cold. Cork is of a light brown colour, and a very fine ſpungy texture, is very ſoft, but requires an extremely ſharp knife to cut it ſmoothly, a dull one only tearing it. It is conſiderably elaſtic, and its ſp. gr. is no more than 0.24, hence it is the moſt buoyant in water of any ligneous ſubſtance. It has a faint peculiar aromatic odour, and little or no taſte. It is readily inflammable, burning with a large yellow flame, which, however ſoon goes out of itſelf, and leaves behind a bulky, ſoft, impalpably pulverulent charcoal.

Water, by long decoction with cork, acquires a browniſh colour, and takes up a quantity of extractive matter in the proportion of about 40 grains from an ounce; of the reſidue alcohol takes up 11 grains. An ounce of cork digeſted firſt in alcohol loſt 42 grains, and by ſubſequent decoction in water 8 grains more. From the ſpirituous tinctures a powdery matter precipitated, of a reddiſh colour when the cork had

not been previouſly boiled with water, but otherwiſe of an aſh-grey.[a]

Cork is corroded, and almoſt entirely diſſolved by nitrous acid, and in 1787 Brugnatelli repeating this experiment, thought that a peculiar acid was thus produced. The inveſtigation was afterwards taken up by B. La Grange with the following reſult.[b] He took finely raſped cork, and added to it in a retort ſix times its weight of moderately ſtrong nitrous acid. By digeſtion at a moderate temperature nitrous gas is given out, the cork ſwells and becomes yellow, and finally is almoſt entirely diſſolved. When the red vapours ceaſe, the liquor is to be transferred into a glaſs capſule, and is to be gently evaporated till it becomes thick, and a pungent vapour begins to be diſengaged. A ſubſtance is thus procured of the conſiſtence of thick honey, of a lemon-yellow colour, and a lively, penetrating, aromatic odour. In order to ſeparate the acid generated in this proceſs from the other matters with which it is mixed, the whole is to be diſſolved in twice its weight of hot diſtilled water, and paſſed quickly through a filter, by which a ſmall quantity of an inflammable ſubſtance analogous to wax will be ſeparated. The clear liquor is of a light amber colour with an odour approaching to that of pruſſic acid. By refrigeration it becomes turbid, and depoſits a pulverulent ſediment which is the acid of cork, or ſuberic acid. The acid yet remaining in the mother liquor may likewiſe be obtained by repeated evaporation and cooling. The ſuberic acid thus prepared is of a yellowiſh-brown colour, but may be whitened by being boiled with freſh burnt charcoal. When pure it is in a ſolid form, but not cryſtallizable; it is acidulous and bitter to the taſte, is volatilizable by a moderate heat, decompoſes all the metallic and many of the earthy ſalts, and combines with the alkalies into cryſtallizable ſalts. Hence it is conſidered by La Grange as a peculiar acid, and Fourcroy has ranked cork, under the name *Suber*, as one of the vegetable principles.

The two chemiſts however, above-mentioned, appear to have been led into an error from not having examined the compoſition of cork previous to treating it with nitric acid, on which account the following facts[c] may not be unacceptable to the reader.

If cork previouſly reduced by filing to extremely fine powder, is digeſted with alcohol, a browniſh-yellow tincture is produced, poſſeſſing the faintly aromatic odour of cork, and cauſing a ſlight ochery precipitate in red ſulphat of iron: this alcoholic ſolution being evaporated to dryneſs by a very gentle heat, leaves behind a brittle browniſh ſediment, of a ſomewhat aſtringent taſte, and conſiderably inflammable. By digeſtion with water a portion of it is diſſolved, conſiſting principally of gallic acid and tannin; for it forms a black precipitate with red ſulphat of iron, and throws down a curdy inſoluble precipitate from a ſolution of iſinglaſs. The portion inſoluble in water appears to be chiefly reſinous, and this, no doubt, it is which marks the peculiar characters of the gallic acid in the alcoholic ſolution. After alcohol has extracted from cork all that it is capable of taking up, the reſidue, when digeſted in a weak ſolution of cauſtic potaſh, acquires a deep reddiſh-brown colour, which it communicates to the menſtruum. Muriatic acid added to ſaturation nearly deſtroys this colour without occaſioning any ſenſible turbidneſs, nor does the neutralized ſolution produce any change in red ſulphat of iron, ſo that it is probable that the alkali diſſolves little or nothing but a ſmall quantity of carbon. Hence it appears likely that the ſuberic acid of La Grange is only gallic acid converted by nitrous acid into oxalic acid, and combined with a little reſinous extract; and that the *ſuber* of Fourcroy conſiſts of vegetable fibre in a very looſe ſtate, mixed with reſinous and extractive matter, and a little tannin and gallic acid.

CORK, MOUNTAIN. See ASBEST.

CORROSIVE SUBLIMATE. See MERCURY, Muriat of.

CORUNDUM.[a] Of this mineral there are the three following ſub-ſpecies.

1. Teleſia. *Perfect Corundum*, Bournon. *Teleſie*, Hauy. *Saphir*, Werner. *Sapphire, Oriental Ruby*, &c. of the jewellers.

Teleſia exhibits a great variety of colours. It is pearl-grey, bluiſh-white, lavender blue, ſky blue, azure or indigo-blue, and then is the ſapphire of the jewellers; or it is peach, crimſon, cochineal, and very rarely carmine red, and is then called oriental ruby; hence it paſſes into violet coloured, forming the oriental amethyſt; when yellow or reddiſh yellow it is denominated oriental topaz; when yellowiſh-green, oriental chryſolite; and when of a deep ſomewhat browniſh green it is named oriental emerald. The colours are for the moſt part uniformly diſtributed, but ſometimes two or more occur in the ſame ſpecimen.

It occurs in ſmall rounded pieces or cryſ-

[a] Neumann, ii. p. 228. [b] Manuel de Chim. ii. p 414. [c] Orig. Experiments.
[a] Greville, Bournon, Chenevix, and Tennant, in Phil. Tranſ. for 1798 and 1802. Jameſon, Hauy, Brochant.

tallized in a ſlightly acute rhomboid or double trihedral pyramid (its primitive figure) of which the obtuſe angles meaſure 94°, and the acute ones 86°.

1. Sometimes the acute ſolid angles, or the ſummits of the pyramids, are replaced by planes perpendicular to the axis, ſituated either above or below, or exactly correſponding with the ſhort diagonal.

2. Sometimes the edges of the baſe of the primitive rhomboid are each of them replaced by a plane parallel to the axis, thus ſeparating the two pyramids by a hexahedral priſm with rhombic planes: when the priſm is long the terminal pyramids often entirely diſappear.

3. Sometimes the flat angles of the primitive pyramids that reſt on the common baſe are replaced by two new planes, thus rendering the pyramids enneahedral as long as any of the primitive faces remain, but when theſe are obliterated forming a dodecahedron, compoſed of two hexahedral pyramids united baſe to baſe. This modification is often combined with No. 1. in conſequence of which the ſummits of the dodecahedron are more or leſs truncated.

4. The acute angles compoſing the ſolid angle at the ſummit of the primitive rhomboid, are ſometimes replaced by ſecondary planes ſo inclined to the axis as to form a very obtuſe ſecondary rhomboid.

The variety in the form of a hexahedral priſm (No. 2.) appears ſometimes to contain within it a ſimilar priſm but of a different colour. The cryſtals are ſmall and very ſmall, rarely middle ſized. It is commonly more or leſs tranſparent paſſing into tranſlucent. The luſtre of the tranſparent kinds is ſhining and vitreous; of the tranſlucent kinds generally gliſtening. When thoſe cryſtals, in which the ſummits of the primitive rhomb are replaced by ſecondary planes, are tranſlucent, the planes juſt mentioned preſent that varying luſtre which is called *chatoyant*: and if theſe cryſtals are cut *en cabochon*, or in the form of an ellipſe, taking care that the ſummit of the ellipſe ſhall be ſituated exactly under the point correſponding with the ſummit of the rhomboid, there will then be produced the appearance of a ſtar with ſix rays. Such ſtones are highly valued by the jewellers, and are called *ſtar-ſtones*.

The fracture of the blue varieties of Teleſia is conchoidal paſſing into foliated; that of the other varieties is foliated. The fragments are indeterminately angular. Its hardneſs is only inferior to that of the diamond, and the blue varieties are uniformly ſomewhat harder than the others. It gives fire with ſteel, but not very eaſily. By colliſion it becomes luminous like quartz, and the light from the red varieties is a very deep fire colour or cherry-red. Its mean ſpecific gravity is about =4. but it varies from 3.907 to 4.161.

It is infuſible *per ſe* before the blowpipe, but when finely pulverized is ſoluble in borax and partially in potaſh. Its extreme hardneſs, and the powerful affinity that ſubſiſts between alumine and ſilex, render it difficult to analyſe. According to Bergman, ſapphire is compoſed of 35 ſilex, 58 alumine, 5 lime, and 2 oxyd of iron. An improved analyſis of the ſame gem was made by Klaproth (by means of cauſtic potaſh) with the following reſults:

98.5	Alumine,
0.5	Lime,
1.0	Oxyd of iron.
100.0	

Finally, Mr. Chenevix ſucceeded, by the help of borax, in decompoſing this ſtubborn mineral, and his analyſes of the ſapphire and ruby may perhaps be looked upon as the moſt correct of any.

	Sapphire.		Ruby.
Silex	5.25	—	7
Alumine	92.	—	90
Iron	1.	—	1.2
	98.25		98.2
Loſs	1.75		1.8

Teleſia occurs in veins in granite and ſyenite. It is found in the kingdom of Pegu and the iſland of Ceylon in the Eaſt Indies. It ſeems to have been found by Count Bournon in the province of Forez in France, and has been met with in the bed of the brook Expailly, in the ſame country. It is ſaid alſo to have been diſcovered in Portugal and Bohemia; and in the North of Italy by Profeſſor Pini.

All the varieties of Teleſia are valuable in jewellery; but rubies, if not very ſmall, bear a conſiderably higher price in proportion to their weight than ſapphires or any of the other varieties. It is ſaid that the light violet coloured pieces may be rendered colourleſs by being heated in a charcoal crucible, without impairing any other of their properties, and that ſuch pieces are often ſold for diamonds.

II. Adamantine Spar. *Imperfect Corundum* of Bournon; *Corund* and *Demantſpath* Werner; *Corindon* Hauy; *Spath adamantine* Broch.

Its colour is greyiſh or greeniſh-white, or yellowiſh-green, or ſapphire blue, or purpliſh-red, or reddiſh-brown. It occurs maſſive, diſſeminated, and cryſtallized in the ſame figures as Teleſia. The cryſtals are middle-ſized and large. Externally they are for the moſt part dull and rough, internally they are tranſlucent, ſemi-tranſparent, and ſometimes, though very rarely, tranſparent. Their ſurface is often covered by ſtrongly adhering ſpangles of mica and grains of magnetic iron ore, which laſt is ſometimes found diſperſed through the interior of the cryſtals. Its internal luſtre is ſhining or gliſtening, between vitreous and reſinous. The terminal faces of ſome of the cryſtals are chatoyant like Teleſia. Its longitudinal fracture is ſtrait-foliated; its croſs fracture is ſmall and imperfectly conchoidal. Its fragments are rhomboidal. Its hardneſs is conſiderably ſuperior to that of quartz, and the blue and red varieties are the hardeſt. It gives fire with ſteel, but not very eaſily. It becomes luminous by friction in the ſame manner as Teleſia. Its mean ſp. gr. is =3.931, varying on the one hand as far as 3.875, and on the other to 3.981.

Adamantine ſpar, in its chemical properties, agrees with Teleſia. Its component parts according to Klaproth and Chenevix are as follows:

	Adamantine Spar from the Carnatic, *Chenevix.*	from Malabar *Chenevix.*	from China *Chenevix.*	from China *Klaproth.*	from Ava *Chenevix.*
Silex	5.	7.	5.25	6.5	6.5
Alumine	91.	86.5	86.5	84.	87.
Iron	1.5	4	6.5	7.5	4.5
	97.5	97.5	98.25	98.0	98.0
Loſs	2.5	2.5	1.75	2.	2.0
	100.	100.	100.	100.	100.

It occurs in veins in granite and ſyenite and other primitive mountains in India, China, and Ava. From its extreme hardneſs, it is in great requeſt in the Eaſt for poliſhing ſteel, and for cutting and poliſhing gems. The European lapidaries however prefer diamond-powder on account of the greater rapidity with which it works,

III. EMERY. *Schmiergel* Werner.

Its colour is intermediate between greyiſh-black, and bluiſh-grey. It occurs maſſive and diſſeminated; when in maſs it is generally incruſted with magnetic iron ore, pyrites and mica; the latter ſubſtance frequently penetrates the whole maſs, giving it when broken a ſilvery appearance. It poſſeſſes a gliſtening or glimmering luſtre. Its fracture is fine-grained, uneven, paſſing into even ſplintery. It is about equal in hardneſs to adamantine ſpar, cutting ſlint and rock cryſtal with great eaſe. It is heavy, and not eaſily frangible. When moſt free from iron it conſiſts, according to Tennant, of about

Silex	3.4
Alumine	92.
Iron	4.6
	100.

When highly impregnated with iron it conſiſts of about

9	Silex
55	Alumine
36	Iron
100	

Emery is chiefly procured from the Iſlands of the Archipelago, eſpecially from Naxos. It is alſo found at Ochſenkopf in Saxony, in beds of talc and ſteatite, accompanied by calcareous ſpar and blende.

It is largely uſed for cutting and poliſhing by lapidaries, and workers in glaſs, ſteel, &c.

The ſubſtance called by Count Bournon compact corundum, and which accompanies adamantine ſpar, is probably an intermediate variety between emery and adamantine ſpar. Its colour is a deep purpliſh-red, it is opake, has a compact ſplintery fracture reſembling a coarſe jaſper It gives ſparks when ſtruck againſt a piece of ſteel, and exhibits a fiery red light by colliſion. It is extremely hard. Sp. gr. 3.9. It generally contains diſperſed through its ſubſtance particles of magnetic iron ore.

CREAM OF LIME. When well-burnt lime is ſlacked by water, it falls into a very fine im-

palpable powder, which, diffuſed in more water to the conſiſtence of cream, remains for ſome time ſuſpended in it, and is then called *Cream of Lime.*

CREAM OF TARTAR. This well-known ſalt is compoſed of tartareous acid in exceſs, united with potaſh. It is therefore accurately defined by the term *Super-tartrite of Potaſh.* (See TARTAREOUS *Acid.*)

CROCUS OF ANTIMONY is a perfect oxyd of ANTIMONY formed by nitre, and from its yellow colour called *crocus* or *ſaffron.*

CROCUS OF MARS. This term is given to ſeveral yellow oxyds of iron, formed by calcination in a red heat either of the ruſt of this metal or of ſulphat of iron. When finely levigated it is much uſed for poliſhing ſteel and other metals. See IRON.

CRYOLITE. *Cryolith,* Karſten. *Alumine fluaté alkaline,* Hauy.

The colour of this mineral is greyiſh-white; it occurs in maſs. Its fracture is lamellar in three directions, giving a rectangular priſm for its primitive form. Its luſtre when broken in the direction of its laminæ is ſhining and vitreous: it is conſiderably tranſlucent, and when immerſed in water it becomes ſemitranſparent. Its hardneſs is inferior to that of fluorſpar; when ſcraped it is of a ſnow-white colour. Sp. gr. =2.95.

When expoſed to the blowpipe it melts at firſt with great eaſe, but after a time becomes covered with a white cruſt, and it is then more difficult of fuſion. It is ſoluble with effervescence in ſulphuric acid, and at the ſame time gives out fluoric acid vapour. It has been analyſed by Klaproth and Vauquelin with the following reſults.

Fluoric acid and water	40.5	—	47.
Soda - - -	36.	—	32.
Alumine - -	23.5	—	21.
	100.0		100

The only ſpecimens of cryolite yet known were brought by a miſſionary from Greenland to Copenhagen, where they lay unnoticed for ſome years, till being examined by Abildgaard, they were found to contain fluoric acid and alumine. The geological hiſtory of this mineral is entirely unknown.

CRUCIBLE. An article of chemical apparatus. *(See the Appendix.)*

CRYSTAL MINERAL or SAL PRUNELLÆ, is an old preparation in chemical pharmacy, now diſuſed, formed by melting a pound of nitre and adding thereto as ſoon as it is red-hot a dram of ſulphur. A detonation takes place and ſulphuric acid is formed, which unites with that portion of the potaſh from which it has expelled the nitric acid. It conſiſts therefore of nitre deprived of its water of cryſtallization, united with a ſmall portion of ſulphat of potaſh.

CRYSTAL *Rock.* See QUARTZ.

CRYSTAL. CRYSTALLIZATION.

Ice, on account of the caſe with which it is liquefied, was called by the Greeks cryſtal (κρυσταλλος); a term which afterwards came to be applied by the Roman naturaliſts to the ſubſtance at preſent named rock cryſtal, becauſe from its colourleſs tranſparency, and its being procured among the Alps and other cold mountainous regions it was ſuppoſed to be only water indurated by continued froſt to a greater degree than common ice, and therefore more permanent. Not only the tranſparency but the remarkably ſymmetrical figure of rock-cryſtal, conſiſting of a ſix-ſided priſm, terminated by a ſix-ſided pyramid, more or leſs perfect, was noticed with ſurprize and delight; and as ſoon as it was obſerved that nitre and certain other ſalts were alſo capable by particular management of exhibiting a ſimilar priſmatic form, the term cryſtal aſſumed a more general meaning and included all thoſe regular polyhædral tranſparent ſolids which are preſented to our notice either by nature or chemiſtry. In this ſenſe the word is employed by the old chemiſts, and the cryſtalline form was conſidered as peculiarly characteriſtic of ſaline ſubſtances. By degrees it was found that the ſame tendency to ſymmetrical arrangement which had been noticed in the claſs of ſalts, obtained alſo in the metallic ores and in a variety of other bodies belonging to the mineral kingdom; and at length ſome able naturaliſts and chemiſts, chiefly of the French ſchool, began to be of opinion that, with the exception of animal and vegetable matter either living or in a ſtate of imperfect decompoſition, every ſolid ſubſtance in nature was capable of cryſtallization. They moreover maintain that each ſpecies has a peculiar characteriſtic form to which all the varieties of cryſtallization that it exhibits may be reduced, and that all amorphous bodies are mere homogeneous or heterogeneous aggregates, in which the proper ſpecific character is obliterated.

All compound bodies (and it is highly probable that moſt of thoſe which chemiſtry is obliged to rank as ſimple are in fact compounded) may be conſidered as made up of *integrant*

particles, each of which is again compoſed of *elementary* ones. Thus a maſs of muriated ſoda conſiſts of a vaſt multitude of little cubes, which are its integrant particles, each of which is reſolvable into muriatic acid and ſoda, which are its elementary particles. With the latter of theſe cryſtallization has nothing to do, nor is it poſſible to aſcertain their forms, ſince they are not decompoſable by means which have any relation to form. Thus when a piece of common ſalt is pounded in a mortar, the concuſſions that it receives are continually deſtroying the adheſion between its integrant particles, and though perhaps it is incapable of being actually and compleatly reſolved, on account of the comparative coarſeneſs of the inſtruments that we are obliged to make uſe of, yet we ſee an evident approximation to this, and cannot doubt that a continuance of the ſame means with more perfect inſtruments would be compleatly efficacious. Now a body that is mechanically diviſible muſt be produced by the adheſion or aggregation of its conſtituent particles, and theſe, both with regard to their forms and the manner in which they adhere to each other, are proper objects of meaſurement and mathematical calculation. The caſe however is widely different with regard to the elementary particles of which the integrant moleculæ are compoſed: theſe are incapable of being in the ſmalleſt degree ſeparated by percuſſion or any kind of mechanical force, and therefore the mode of their combination is not capable of being explained by geometrical calculation.

All the integrant particles of the ſame ſubſtance are of the ſame figure, and the great varieties that appear in its cryſtalline forms are owing to the different modes in which its particles are aggregated upon each other. This is evident, becauſe by dividing the moſt complex cryſtals in the direction of their laminæ, a regular figure called the nucleus or primitive figure will be at length produced, which is further diviſible only in a direction parallel to its ſides, and the correſponding angles of which in any number of ſpecimens will be found to be ſtrictly equal. But though the nuclei of all cryſtals belonging to the ſame ſpecies accurately correſpond with each other in their form and the dimenſions of their angles, yet it is by no means true, as has been haſtily aſſerted, that every ſpecies has a peculiar primitive form. Thus boracite, muriat of ſoda, galena and iron pyrites have the ſame primitive form, namely a cube, and the ſame integrant molecule which is a cube alſo. In like manner fluor ſpar, alum, ſpinelle ruby, diamond, ruby copper, biſmuth and antimony afford by calculation and mechanical diviſion a regular octohedron for their primitive figure, compoſed of regular tetahedral integrant particles. With the exception however of theſe nuclei, which are regular geometrical ſolids, and therefore unſuſceptible of any variety in their dimenſions, it may be affirmed that no two nuclei of different ſpecies have preciſely the ſame dimenſions; thus the primitive form both of calcareous ſpar and tourmaline is an obtuſe rhomboid, but in the former the obtuſe angles are $= 101° 32'$, while in the latter they are $= 113° 34'$. The primitive forms that have hitherto been obſerved are the following: 1. the cube; 2. the regular octohedron; 3. the regular tetrahedron; 4. the rhomboidal dodecahedron; 5. the rhomboid; 6. the octohedron compoſed of two pyramids, with ſquare, rectangular or rhombic baſes; 7. the tetrahedral priſm either ſtrait or oblique, with ſquare, rectangular or rhombic baſes; 8. the regular hexahedral priſm; 9. the pyramidal dodecahedron.

It has been the practiſe of ſome late authors to extend the meaning of the term cryſtallization ſo as to make it ſynonimous with the attraction of aggregation; this however appears to be injudicious; the latter comprehends every ſpecies of formation by which ſolids are produced, but the former expreſſes only that regular arrangement of homogeneous integrant particles by which, when interrupted, cryſtalline laminæ, and when uninterrupted, entire cryſtals, are produced; aggregation therefore includes cryſtallization, which is only a mode or ſpecies of the former. It is of importance to bear in mind that not only a regular external figure, but a regular internal ſtructure is neceſſary to conſtitute a cryſtal; otherwiſe a column of baſalt might be conſidered as a priſmatic cryſtal, an error which ſome of the older mineralogiſts have actually fallen into.

The integrant moleculæ of different ſubſtances appear to be poſſeſſed of very different degrees of cryſtalline polarity; the relative force of which may be eſtimated in ſome meaſure from the comparative quantity of extraneous matter with which they may be intimately mixed without annulling their power of cryſtallization, and partly alſo from the proportion which cryſtals of any ſpecies bear to the uncryſtallized maſſes of the ſame. For this reaſon carbonat of lime may be conſidered as endowed with a high degree of cryſtalline polarity, for not only are cryſtals of this ſubſtance exceedingly abundant

but they occur with all the geometrical characters of calcareous ſpar, even when mixed with a very large portion of foreign ingredients. Thus the acute rhomboids of calcareous ſpar which are found at Fontainbleau, contain more than two-thirds of their weight of granular quartz: the primitive figure and cryſtalline varieties of pearl ſpar are preciſely thoſe of calcareous ſpar, although, in many inſtances, the carbonat of lime in this mineral amounts to no more than about a third of its weight, the remainder being oxyd of iron and manganeſe; again in the bitterſpath the carbonat of lime preſerves its eſſential cryſtalline character though mixed with nearly half its weight of carbonated magneſia. On the other hand, the cryſtalline polarity of ſulphuret of copper is probably but ſmall, on account of the minuteneſs of its cryſtals, and their comparative rarity.

Hardly any of the cryſtallizations that are performed by nature have been imitated by art; in return, however, chemiſtry has been able to effect the cryſtallization of a variety of ſubſtances, chiefly ſalts, which are not found cryſtallized naturally; and by taking proper advantage of this circumſtance has ſucceeded in obtaining them in a ſtate of greater purity than any other method could afford them.

All ſubſtances in order to be cryſtallized require that their integrant molecules ſhould be ſeparated from each other by the intervention of a medium in which they may move freely according to the attraction of their cryſtalline polarity. But this neceſſarily implies two diſtinct operations; for the ſame attraction exerted by the medium or ſolvent to overcome the aggregation of a body, and reduce it to its integrant molecules will alſo prevent the efficacy of its cryſtalline polarity. It is neceſſary therefore after having annulled the aggregation of a ſolid by the requiſite quantity of a ſolvent, to abſtract by degrees ſuch a portion of it that the attraction of the remainder ſhall be inferior to the cryſtalline polarity of the ſubſtance diſſolved. The ſimpleſt ſolvent that can be employed is caloric, and many great advantages attend its excluſive uſe; a number of caſes however occur, in which its application is impracticable, except in combination with ſome liquid menſtruum, as water or alcohol.

Solids that are eaſily volatilized without decompoſition at a moderate temperature, may be obtained in a cryſtalline ſtate by gradual ſublimation in cloſe veſſels. Thus when grey oxyd of arſenic is expoſed to a low red heat the aggregation of its integrant molecules is deſtroyed, and it is converted into a vapour which at the ſame or any higher temperature would continue in a permanently elaſtic ſtate. This is the firſt part of the proceſs, namely the ſeparation from each other of the integrant particles of the arſenic, in conſequence of the addition of caloric, which interpoſes itſelf between them: the ſecond part of the proceſs, or the formation of cryſtals depends on the tendency to an equilibrium by which it is characterized, and its being able to paſs with readineſs through media that are impermeable to other bodies. When, therefore, the vapour, conſiſting of caloric and oxyd of arſenic, arrives in the upper part of the veſſel, the caloric paſſes through, like water through a filter, while the oxyd of arſenic is left behind; this latter, therefore, is continually increaſing in proportion to the remaining caloric, till the cryſtalline polarity of the particles of arſenic becomes ſuperior to the attraction of the caloric. As ſoon as this takes place, a ſtratum of particles begins to be depoſited on the inner ſurface of the containing veſſel, and theſe ſerve as a baſis to which all the ſucceeding ones attach themſelves according to their peculiar mode of arrangement, in proportion as their cryſtalline attraction becomes ſuperior to the affinity exerted by the caloric. In this way not only are volatilizable ſubſtances when unmixed with others obtainable in a pure cryſtalline ſtate, but they may often be ſeparated hereby from intimate mixture or combination with bodies of greater fixity. Thus benzoic acid is ſeparable in a cryſtalline form from the reſin with which it is naturally combined by taking advantage of its ready volatility at a moderate heat: thus alſo the manufacturers of ſal-ammoniac ſeparate this ſalt from ſulphat of ſoda, and procure it of a cryſtalline texture by the application of a degree of heat ſufficient to ſublime the former, while it has no ſuch action in the latter.

Bodies may be made to aſſume the cryſtalline ſtate not only by the proceſs of ſublimation but in many caſes by a temperature only ſufficient to fuſe them. If a maſs of biſmuth is melted in a crucible, and allowed to cool gradually, although its external figure is caſual or amorphous, yet its internal texture will be found to be completely lamellar in two or three directions, or cryſtalline; and if the external lamellæ are ſucceſſively removed from the ſurface of a fragment, of the ſize of a hazle nut for example, a regular octohedron will at length be obtained which is the primitive form of this metal. Not only the texture but even the cryſtalline figure of biſmuth, may be obtained by fuſion with a

little management: the metal being melted in an iron ladle held in a flanting direction, is to be cooled very gradually, and when it begins to conſolidate, the ladle being gently and gradually inclined in the oppoſite direction, the fluid part of the metal will flow off from that which has become fixed, and thus a group of cubical cryſtals will be obtained. A better way of obtaining cryſtals of biſmuth, as well as of antimony, ſulphur, the ſulphurets of biſmuth and antimony, and ſome other ſubſtances, is to melt a conſiderable quantity in a crucible, and afterwards to cool it as ſlowly as poſſible, till a thin cruſt has formed upon the ſurface, two ſmall oppoſite apertures being then made through the cruſt with a pointed iron, the fluid portion is to be quickly poured out by one opening while the air enters by the other: when the crucible with its contents is grown cold, the cruſt is to be carefully removed by a chizel or other ſuitable inſtrument, and a cup-ſhaped hollow will preſent itſelf ſtudded with cryſtals more or leſs perfect according to the magnitude of the original maſs, the ſlowneſs with which it has cooled, and the dexterity with which the fluid part has been evacuated.

There are, however, but few chemical ſubſtances, comparatively, that can be obtained in a cryſtalline ſtate by the agency of heat alone; for ſome are decompoſable by fire, and others are either infuſible or require ſuch a high temperature for this purpoſe as to make its application exceedingly troubleſome and inconvenient. In effecting the cryſtallization of nearly the whole of the compound ſalts and a few other bodies, recourſe has been had to the agency principally of water and alcohol, as theſe two fluids exert a conſiderable ſolvent power on the ſubſtances expoſed to their action, without however decompoſing them; and being themſelves readily volatile at a moderate temperature, they may be abſtracted with ſufficient ſlowneſs to allow the ſubſtances held by them in ſolution to be depoſited in a cryſtalline form.

When a maſs of ſalt, nitre for example, is immerſed in water of the common temperature, the cohefive attraction of its particles is oppoſed by the ſolvent power or chemical attraction of the water. At firſt, the nitre, being ſurrounded on all ſides by particles of uncombined water, begins to be rapidly diſſolved; but as the ſolution proceeds, this effect becomes more and more languid, till at length it entirely ceaſes, when the number of uncombined particles of water is ſo far reduced that the ſum of the ſolvent forces of thoſe which are in contact with the nitre, exactly counterbalances the attraction of cohefion by which the undiſſolved reſidue of the nitre is held together. When this ſtate of equilibrium takes place the ſolution is ſaid to be ſaturated; but although this is the caſe as long as it undergoes no increaſe of temperature, yet in proportion as the heat of the water is raiſed the ſolvent power of the liquid is greatly augmented. The ſalt therefore that is contained in boiling hot water may be conſidered as rendered fluid by the combined action of the heat and water, and if this menſtruum is completely ſaturated, it is manifeſt that in proportion as it cools the cohefive attraction between the particles of nitre will gain the aſcendency, and continue to act till the oppoſing forces of the ingredients of the ſolution find themſelves again in equilibrium. All ſalts therefore which are more ſoluble in hot than in cold water, are in part depoſited from a ſaturated ſolution by mere cooling, and if this is done gradually, and without the interference of any materially diſturbing cauſe, the particles as they conſolidate will arrange themſelves in regular cryſtals. When a ſolution of this kind has depoſited by cooling, all the ſaline particles which it was enabled to hold by its increaſed temperature, in addition to thoſe which were retained by the mere action of the water, it is obvious that recourſe muſt be had to the abſtraction of the liquid menſtruum itſelf if we wiſh to procure from it any additional cryſtals. We therefore ſubject the whole to a boiling heat which has the double advantage of driving off part of the water, and enabling the remainder in conſequence of the increaſed temperature ſtill to hold the ſalt in ſolution. When the evaporation has proceeded for ſome time, a ſaline pellicle begins to appear on the ſurface of the liquor, which is a proof that the cohefive attraction of the particles of the ſalt is obtaining a ſuperiority over the ſolvent power of the hot water, and by continuing the evaporation the whole of the water will be driven off, and the ſalt depoſited in an amorphous uncryſtallized maſs: but if when the pellicle appears the ſolution is ſlowly cooled, it will depoſit, as at firſt, in a cryſtalline ſtate all that portion of ſalt which in the cold ſaturated ſolution was combined with the water that has been evaporated. Thus by ſucceſſive evaporation and gradual cooling all ſubſtances capable of cryſtallizing, and which are more ſoluble in hot than in cold water, may be procured in their proper cryſtalline forms.

A few ſalts, eſpecially muriat of ſoda, are

nearly equally ſoluble in water of any temperature, theſe therefore can only be obtained in a cryſtalline ſtate by evaporation, and to ſucceed completely requires conſiderable management. If the ſolution is made to boil the evaporation it is true goes on rapidly, but the commotion thus occaſioned in the liquor prevents that orderly depoſition of the ſaline particles which is abſolutely requiſite in order to obtain large and well formed cryſtals: neither muſt the evaporation be very ſlow otherwiſe the particles as they ſeparate from the liquors are principally attracted to the ſides of the veſſel up which they aſcend, thus lining the upper part of it with an amorphous cruſt, while hardly any cryſtals are depoſited at the bottom of the veſſel.

All cryſtals that are formed in water return a portion of this fluid, which is called the *water of cryſtallization*. Its proportion varies according to the nature of the ſalt that is cryſtallized, and appears to be in an inverſe ratio to the force of its cryſtalline polarity. Thus ſulphat of potaſh, which requires a large quantity of water to counterbalance the coheſive force of its particles contains but little water of cryſtallization, whereas ſulphat of ſoda which is readily ſoluble in water, holds more than half its weight of water. This water appears to be in a ſtate of chemical combination with the ſalt, and not ſimply interpoſed between its cryſtalline laminæ; the affinity however which it exerts is but feeble, at leaſt in thoſe ſalts into the compoſition of which it enters largely, ſince a conſiderable proportion of it is driven off by ſimple expoſure to the air. In theſe caſes the cryſtal moulders away to powder, and entirely loſes its peculiar figure and texture; hence it has been argued that this water is eſſential to the figure of all the ſalts in which it exiſts: in ſome degree no doubt it is, for if the water is haſtily driven off, the texture of the cryſtal is entirely deſtroyed, and there are no facts as yet obſerved to prove the poſſibility of the earthy ſulphats aſſuming a cryſtalline form by any other medium than water, yet the following fact ſeems to ſhow that the *form* of the cryſtal is not liable to be greatly modified by the water of cryſtallization. If a number of cubes of common ſalt, produced by evaporation in the uſual manner, are placed in a covered veſſel over the fire, as ſoon as they become heated they decrepitate, or fly to pieces with a crackling noiſe on account of the evaporation of their water of cryſtallization: when this noiſe ceaſes the water is driven off, and the ſalt has loſt its cubic ſhape and cryſtalline texture, and is reduced to a fine white powder: by augmenting the heat this powder enters into fuſion, and when cooled ſlowly exhibits again its cryſtalline texture, and breaks into cubical fragments in the ſame manner as before it was heated.

If a cryſtallizable ſalt is perfectly pure, its ſolution will continue to afford cryſtals by the common treatment to the very laſt drop: but as all ſalts have a greater or leſs chemical action on each other, it uſually happens when two or more coexiſt in the ſame ſolution, that after cryſtals have been obtained by ſucceſſive evaporations and coolings, the remaining portion of fluid, though charged to ſaturation with ſaline matter, refuſes to yield any more cryſtals. This liquor, whatever may be the nature of its contents, is known by the general appellation of *Mother water*. Thoſe ſalts, the cryſtals of which are permanent in the air, have the ſtrongeſt degree of cryſtalline polarity; in thoſe which are effloreſcent this force is conſiderably leſs, but it is the weakeſt of all in thoſe that deliqueſce on expoſure to the air. Now if two ſalts of the firſt claſs are diſſolved together in the ſame quantity of water, provided they do not decompoſe each other, and eſpecially if their ratios of ſolubility are different, although they are rendered more ſoluble by their mutual affinity, yet they may be obtained again in a cryſtalline ſtate without leaving any mother water. Thus equal parts of nitrat of potaſh and ſulphat of potaſh, though ſoluble when mixed together in leſs water than would have been neceſſary for both ſeparate, afford by evaporation ſucceſſively and in proportion to their ſolubility, firſt, ſulphat of potaſh, and then nitrat of potaſh, without leaving any uncryſtallizable liquid. But on the other hand if nitrat of ſoda and ſulphat of ſoda are ſubjected to the ſame experiment, both of which have only a ſlight tendency to cryſtallize and are of nearly equal ſolubility, only a ſmall quantity of ſulphat of ſoda will ſeparate by cryſtallization, all the nitrat and the remainder of the ſulphat remaining liquid and uncryſtallizable. When the mutual action of the two ſalts is ſufficient to effect a double decompoſition of them, it is neceſſary to take into conſideration the ſolubility of the new ſalts, in order to make a correct eſtimate of the quantity of uncryſtallizable reſidue. Thus if equal parts of ſulphat of magneſia and muriat of ſoda are mixed together, although the ratio of ſolubility of the two is different, and their force of cryſtallization is alſo conſiderable, yet the liquor can hardly be made to yield any cryſtals at all; for in conſequence of

a mutual decompoſition, muriat of magneſia a deliqueſcent ſalt, and ſulphat of ſoda an efflo-reſcent one, will be formed, and the ſlight cryſtalline force of the latter will be almoſt wholly annulled by the extreme ſolubility of the former.

It has been already mentioned that the diſturbance occaſioned by ebullition and other cauſes of agitation prevents the formation of regular cryſtals: the converſe however of this is not true, namely that the entire abſence of external motion is peculiarly favourable to regular cryſtallization. The ſolutions of thoſe ſalts that are much more ſoluble in hot than in cold water, and have but a feeble power of cryſtalline polarity may, if kept ſtill, be cooled by degrees conſiderably below their congealing or cryſtallizing point, and ſtill retain their fluidity; apparently, becauſe the attraction of their particles, in itſelf feeble, and oppoſed by the affinity of the water, is held in equilibrium becauſe no one particle has a preponderating power over thoſe in its vicinity; for if a piece of the ſame kind of ſalt that is contained in the ſolution be introduced even with the utmoſt precaution, the ſuperior attraction of the maſs will be immediately exerted on the neighbouring particles, and a rapid growth of cryſtals will take place, radiating from this maſs as their centre of attraction. Cryſtallization may alſo be induced in ſimilar circumſtances merely by agitation, but when this is the caſe it is always confuſed and irregular.

For further particulars connected with this ſubject ſee AFFINITY, SOLUTION, PRECIPITATION.

CUCURBIT is an article of chemical apparatus. (See the Appendix.)

CULM. See COAL.

CUPEL is a ſmall crucible uſed in the proceſs of cupellation.

CUPELLATION. *Abtreiben*, Germ. This important proceſs in metallurgic chemiſtry is deſcribed at length under the article ASSAY.

CURCUMA. See TURMERIC.

CYANITE.* *Kyanit*, Werner. *Sappare*, Sauſſure. *Diſthene*, Hauy.

Its colour is milk-white, pearl-grey, bluiſh-grey, or ſmalt-blue, Pruſſian blue or ſky-blue. It ſometimes occurs entirely blue, but more frequently ſpotted, ſtriped or clouded with this colour. It is found in maſs, diſſeminated, and cryſtallized in long oblique four-ſided priſms, truncated on the lateral edges. The cryſtals are imbedded or interſect one another, and vary from middle-ſized to very ſmall. Its external and internal luſtre is bright-ſhining pearly. Its fracture is broad diverging and interſecting radiated, paſſing into curved-foliated. The fracture of the cryſtals is foliated in three directions. Its fragments are flaty and ſometimes imperfectly rhomboidal. In maſs it is uſually tranſlucent; the cryſtals are for the moſt part tranſparent. Its hardneſs is about equal to that of fluorſpar. It has a ſlight degree of flexibility, and feels ſomewhat greaſy. Sp. gr. 3.51 to 3.62.

It is infuſible *per ſe* before the blowpipe. Its component parts, according to Theodore de Sauſſure, are

29.2	Silex,
55.	Alumine,
2.25	Lime,
2.	Magneſia,
6.65	Oxyd of iron,
6.9	Water and loſs.
100.00	

It occurs in primitive mountains imbedded in micaceous ſchiſtus and accompanied by grenatite.

It is found near Banchory in Aberdeenſhire, and in the largeſt of the Shetland iſlands; alſo in Norway, the Swiſs Alps, the Pyrennees, the Tyrol, Carinthia, Bavaria, France and Siberia.

The very pale varieties of this mineral are ſometimes miſtaken for tremolite; it may be diſtinguiſhed however by the blue tinge which even the paleſt are not entirely free from: beſides tremolite is found chiefly in granular limeſtone, but cyanite in micaceous ſchiſtus. The tranſparent varieties of a Pruſſian blue colour are ſometimes when cut and poliſhed ſold for ſapphires, from which however they are readily diſtinguiſhed by their inferior hardneſs and ſpecific gravity.

CYMOPHANE. See CHRYSOBERYL.

* Hauy, Brochant, Emmerling, Jameſon.

D

DAOURITE. See SCHORL.

DECOCTION. *Abkochen-Abſieden*, Germ. Is the extraction of the ſoluble part of any ſubſtance by means of boiling, generally with plain water. Decoction is one of the ſimpleſt and moſt efficacious methods employed in the analyſis of vegetable and animal matters. It is alſo largely uſed in pharmacy.

DECOMPOSITION. *Zerſetzung*, Germ. Moſt of the proceſſes in chemiſtry are attended with the diſunion of ſubſtances already joined together, or decompoſition, and the conſequent formation of new compounds. In the Appendix will be given moſt of the known decompoſitions produced by the mixture of the common chemical ſubſtances.

DECREPITATION. *Decrepitiren-Abknifiern*, Germ.

When hard cryſtals of any ſaline ſubſtance containing but little water of cryſtallization are heated ſuddenly, they do not liquefy as the watery ſalts do, but crack and fly in pieces with vehemence, owing to the eſcape of the water, which is called *decrepitation*. Common ſalt affords a familiar example of this, and for convenience when uſed as a flux in the reduction of minerals it ſhould be previouſly decrepitated.

DEFLAGRATION. This term expreſſes a gradual ſparkling combuſtion of any ſubſtance without violent exploſion. It is particularly applied to many inſtances of combuſtion produced by nitre.

DELIQUESCENCE. *Zerflieſſen*, Germ. Is the ſpontaneous liquefaction of any ſalt by ſimple expoſure to air. Potaſh is an example of the kind. As the deliqueſcent ſalts abſorb moiſture from the air they are of uſe in rendering air dry, which is often required for nice experiments.

DEMANTSPATH. See CORUNDUM.

DEPHLEGMATION. *Entwaſſern*, Germ. Is the depriving any liquid of part of the ſuperfluous water which it may contain, and thus it has the effect of concentration. Thus ſulphuric acid is dephlegmated by boiling for a time, which expels at firſt little elſe than mere water. Vinegar is dephlegmated by partial freezing, the ice that firſt forms being only the watery portion containing none of the acid.

DEPHLOGISTICATED AIR. See OXYGEN.

DEPHLOGISTICATED MARINE ACID. See OXYMURIATIC ACID.

DEPHLOGISTICATED NITROUS AIR. See NITROUS OXYD.

DERBYSHIRE SPAR. See FLUOR SPAR.

DESICCATION is the compleat drying of any ſubſtance.

DETONATION. *Verpuffen*, Germ. Is exploſion accompanied with loud noiſe. A ſudden evolution of light attends moſt inſtances of detonation. *Fulmination* has a ſimilar meaning.

DIAMOND.* *Demant* Werner; *Diamant* Hauy and Broch.

The diamond is either colourleſs, or of a light yellow, or ſmoak-grey paſſing into bluiſh, or pearl grey, or clear wine colour, on one hand deepening into clove brown, and paſſing on the other into yellowiſh green: it alſo occurs of a deep almoſt black brown, pruſſian blue or roſe red. The colourleſs varieties are the moſt eſteemed, and are perhaps the moſt frequent; next to theſe in value are the black, blue, and red, they are alſo by far the rareſt, the light coloured are in the leaſt eſtimation.

It is found cryſtallized in the regular octohedron (which is its primitive form) compoſed of two four-ſided pyramids applied baſe to baſe. Sometimes each triangular facet of the primitive octohedron is replaced by ſix ſecondary triangles bounded by curvilinear lines, in which caſe the whole cryſtal has forty-eight facets, and is of a ſpheroidal figure. Other ſpheroidal varieties of this mineral are the dodecahedron, a ſolid of 24 facets, and a compreſſed ſpheroid reſembling a very ſhort ſix-ſided priſm, terminated by very ſhort curvilinear pyramids. Sometimes the pyramids of the octohedron, inſtead of ending in a point terminate in a line, whence reſults a rhomboidal quadrangular priſm with dihedral ſummits.

The ſurface of the regular octohedrons is generally ſmooth and ſhining, that of the other varieties is ſomewhat dull and rough; but internally, eſpecially when cut and poliſhed, they are all of extreme brilliancy, far ſurpaſſing both in luſtre and lively play of priſmatic colours every other ſubſtance. Rough diamonds are uſually covered with a very thin cruſt, which renders them ſemi-tranſparent, but when this is removed they are tranſparent, though

* Hauy, R. de Liſle, Brochant, Jameſon.

ſomewhat inferior in this reſpect to rock cryſtal. The fracture of diamond is ſtrait foliated, its lamellæ being parallel to the ſides of a regular octohedron. Its hardneſs is ſuperior to that of all other bodies natural or artificial, it yields however to corundum by long continued friction. It is brittle, and not difficultly frangible. Sp. gr. 3.518—3.550.

Diamond, even when rough, acquires, by friction, the vitreous or poſitive eléctricity. It becomes phoſphoreſcent when expoſed either to the entire rays of the ſun, or to the blue ones alone when ſeparated by the priſm, and concentrated on the diamond by means of a lens: a ſimilar effect is alſo produced by fixing it to the end of a charged conductor, and taking a few electric ſparks from it. Many diamonds however are incapable of becoming phoſphoreſcent, although agreeing in colour, tranſparency, &c. with thoſe which readily become luminous. Thoſe which are ſmall acquire this property by a much ſhorter expoſure to the light than the larger ones: ſometimes a diamond that is not phoſphoreſcent by the ſimple action of the ſolar light, may be made ſo by previouſly immerſing it for ſome time in melted borax.[b]

Diamond when expoſed to a current of air, and heated to the temperature of melting copper, is gradually but completely combuſtible, and is ſurrounded, during the proceſs, by a luminous areola. It is wholly converted into carbonic acid, and therefore conſiſts of pure carbon, as we have already mentioned under that article.

The art of cutting and poliſhing diamonds was probably known to the inhabitants of Hindoſtan and China at a very early period; the only material however that is uſed in the Eaſt for this purpoſe, being corundum, and the apparatus being of extreme ſimplicity, the jewellers of theſe countries are incapable of bringing out the peculiar beauty of the diamond in a degree at all comparable to what is readily effected by European artiſts. The extreme hardneſs of this gem had baffled the attempts of the jewellers of Europe till the year 1456, when a young man named Louis de Berquin, a native of Bruges, endeavoured to poliſh two diamonds by rubbing them againſt each other; he found that by this means a facet was produced on the ſurface of the diamonds, and in conſequence of this hint, conſtructed a poliſhing wheel, on which, by means of diamond powder, he was enabled to cut and poliſh this ſubſtance in the ſame manner as other gems are wrought by emery. Previous to this diſcovery, diamonds were ſet in jewellery preciſely in the ſtate in which they arrived from India, and hence the regular octohedrons were much more eſteemed than the reſt, both on account of the regularity of the figure, and the ſuperiority of its natural poliſh.

Diamonds are cut and manufactured by jewellers[c] into brilliants and roſe diamonds; the former being for the moſt part made out of the octohedral cryſtals, and the latter from the ſpheroidal varieties. To faſhion a rough diamond into a brilliant the firſt ſtep is to modify the faces of the original octohedron, ſo that the plane formed by the junction of the two pyramids ſhall be an exact ſquare, and the axis of the cryſtal, or a line connecting the apices of the pyramids, and perpendicular to this common baſe, ſhall be preciſely twice the length of one of the ſides of the ſquare. The octohedron being thus rectified, a ſection is to be made parallel to the common baſe or *girdle*, ſo as to cut off $\frac{2}{3}$ of the whole heighth from the upper pyramid and $\frac{1}{3}$ from the lower one: the ſuperior and larger plane thus produced is called the *Table*, and the inferior and ſmaller one is named the *Collet*: in this ſtate it is called a *complete ſquare table diamond*. To convert it into a brilliant, two triangular facets are placed on each ſide of the table, thus converting it from a ſquare to an octagon, a lozenge-ſhaped facet is alſo placed at each of the four corners of the table, and another lozenge extending lengthways along the whole of each ſide of the original ſquare of the table, which, with two triangular facets ſet on the baſe of each lozenge, completes the whole number of facets on the table ſide of the diamond, viz. eight lozenges and twenty-four triangles: on the collet ſide are formed four irregular pentagons alternating with as many irregular lozenges, radiating from the collet as a centre, and bordered by ſixteen triangular facets adjoining the girdle. The brilliant being thus completed is ſet with the table ſide upwards, and the collet ſide implanted in the cavity made to receive the diamond. The regular roſe diamond is formed by inſcribing a regular octagon in the centre of the table ſide of the ſtone, and bordering it by eight right angled triangles, the baſes of which correſpond with the ſides of the octagon; beyond theſe is a chain of eight trapeziums, and another of ſixteen triangles. The collet ſide conſiſts alſo of a minute central octagon, from every angle of which proceeds a ray to the edge of the girdle, forming the whole ſurface into eight trapeziums,

[b] Groſſer in Journ. de Phyſ. xx. p. 270.

[c] Jeffries on Diamonds, p. 9.

each of which is again ſubdivided by a ſaliant angle, the apex of which touches the girdle, into one irregular pentagon and two triangles. In the formation of either a brilliant or roſe diamond of regular proportions, ſo much is cut away that the weight of the poliſhed gem is no more than half that of the rough cryſtal out of which it was formed, whence the value of a cut diamond is eſteemed equal to that of a ſimilar rough diamond of twice the weight, excluſive of the value of the workmanſhip. The weight, and conſequently the value of diamonds, is eſtimated in carats, 150 of which are equivalent to 240 grains or 1 oz. Troy, and the difference between the coſt of one diamond and another, *ceteris paribus* is as the ſquares of their reſpective weights. Thus the value of three diamonds of one, two, and three carats weight reſpectively, is as one, four, and nine. The average price of rough diamonds, that are worth working, is about 2 pounds ſterling for the firſt carat, and conſequently in wrought diamonds, excluſive of the coſt of workmanſhip, the coſt of the firſt carat is = 81. Hence a wrought diamond of

	£
5 carats is worth	200
10 ditto ——	800
20 ditto ——	3,200
30 ditto ——	7,200
40 ditto ——	12,800
50 ditto ——	20,000
60 ditto ——	28,800
70 ditto ——	39,200
80 ditto ——	51,200
90 ditto ——	64,800
100 ditto ——	80,000

This rule however actually holds good only in the ſmaller diamonds of twenty carats and under, the larger ones, in conſequence of the ſcarcity of purchaſers, being diſpoſed of at prices greatly inferior to their eſtimated worth. The largeſt diamond at preſent known is in the poſſeſſion of the Emperor of Ruſſia, it weighs 779 carats. The Pitt or Regent Diamond, the fineſt of the crown jewels of France, weighs 136 carats, and was purchaſed for 2,500,000 livres.

The mineralogical ſituation of the diamond is not well aſcertained: it occurs in India in detached cryſtals, in a kind of indurated ochery gravel, but whether or not this is its native bed is unknown. The diamond mines of India are diſperſed throughout the whole chain of the Ghauts from Bengal to Cape Comorin; many of theſe are however at preſent abandoned, the chief that are now worked being ſituated between Golconda and Mazulipatam. The earth which affords them being dug up and broken to pieces is carefully waſhed till the water comes off colourleſs, and the reſidue is ſpread thin on mats in the ſun, where the diamonds are diſcovered by their ſuperior brilliancy.[d] This valuable gem is alſo procured from Borneo and from Brazil in the mountainous diſtrict called Serro Doſrio contained in alluvial beds of ferruginous ſand.[e]

The principal uſe of diamond is in ornamental jewellery; it is alſo employed by glaziers and lapidaries to cut glaſs, and engrave upon the harder gems; and in the finer kinds of clockwork.

DIAPHORETIC *Antimony* is a perfect oxyd of this metal made by deflagration with nitre. See ANTIMONY.

DIGESTER is an article of chemical apparatus. (See the Appendix.)

DIGESTION. *Digeriren*, Germ. Is the long continued expoſure of a ſubſtance to the action of any menſtruum kept at a nearly uniform temperature, generally above that of the common atmoſphere.

DIGESTIVE *Salt* is the old term for ACETITE *of Potaſh*.

DIPPEL'S OIL, ſo called from the inventor, is the oil that riſes during the diſtillation of bone or horn, highly rectified by ſubſequent and repeated diſtillation. See BONE.

DIPYRE.[a]

The colour of this mineral is greyiſh or reddiſh white, paſſing into pale roſe colour. It occurs either diſſeminated in ſmall faſcicular maſſes, or in minute priſmatic cryſtals. It has a brilliant vitreous luſtre, a lamellar fracture parallel to the ſides of a regular hexahedron. It is moderately hard, eaſily frangible. Sp. gr. = 2.63.

It is fuſible with ebullition before the blowpipe, and contains according to Vauquelin,

60	Silex
24	Alumine
10	Lime
2	Water
96	
3	Loſs
100	

When pulverized and thrown on a hot coal

[d] Phil. Tranſ. xii. p. 907. [e] Andrada in An. de Chim. xv. p. 82. [a] Brochant, ii. p. 508.

it gives a pale phoſphoric light. It occurs at Mauleon in the Pyrennees, imbedded in ſteatite.

DISTHENE. See CYANITE.

DISTILLATION. *Deſtilliren*, Germ. Is the proceſs of evaporation performed in veſſels adapted to condenſe or collect the ſubſtance evaporated.

Diſtillation in the large way is uſually carried on in an apparatus compoſed of three parts, namely, the alembic or boiler in which the ſubſtance is heated; the head or capital, a dome-ſhaped continuation of the former in which the vapours are collected, and a tube or worm ſpirally diſpoſed and paſſing through a tub of water, in which the diſtilled vapour is condenſed into a liquid. For ſmaller purpoſes this apparatus is often ſimplified, and the capital is encloſed in a caſe which holds cold water, whereby the condenſation takes place in the capital itſelf.

Another apparatus more uſual in experiments is a retort, generally of glaſs, which anſwers the purpoſe both of boiler and capital, and a globe-ſhaped receiver fitting to the retort in which the condenſation is compleated. The greateſt improvement perhaps ever made to chemical apparatus is the (comparatively) modern addition of a ſeparate ſeries of tubes and veſſels to convey and collect the gaſeous products, and to avoid all the danger from ſudden expanſion without incurring the neceſſity (formerly required) of letting off to waſte a large portion of the difficultly condenſible, but often moſt important, products of the operation.

The practical uſes of diſtillation in chemiſtry are too numerous to be mentioned. By it the volatile part of any ſubſtance is ſeparated from that which is fixed, as in the diſtillation of turpentine, in which the eſſential oil riſes and the roſin is left behind: the more evaporable is ſeparated from the leſs evaporable, as in the preparation or rectification of ardent ſpirit; liquids are freed from foreign or accidental impurities, as in the diſtillation of common water: volatile ſubſtances are united in an eaſy and commodious manner, as in preparing the odorous diſtilled waters of aromatic vegetables: bodies are decompoſed and analyzed, new compounds are formed, and a knowledge is gained of the native and chemical properties of natural ſubſtances.

When the products of diſtillation are ſolid and dry, the proceſs is uſually termed *ſublimation*.

The apparatus for the different proceſſes will be deſcribed in the Appendix.

DISTILLED WATERS. On this large claſs of chemical preparations, but almoſt entirely devoted to pharmacy, a few obſervations may be made.

The object of them all is to impregnate water ſolely with the aromatic or flavouring principles of plants or parts of plants, leaving behind all the other ſoluble matter. There is every reaſon to believe that the ſubſtance which flavours the diſtilled waters of vegetables is eſſential oil, becauſe in moſt inſtances a portion of eſſential oil actually ſeparates from the water when recently diſtilled, becauſe the ſenſible properties of the water are nearly the ſame as when a few drops of the eſſential oil of the plant are mixed with pure water by ſimple agitation, becauſe in the proceſs of diſtillation the condenſed liquor becomes gradually leſs and leſs flavoured in proportion as the eſſential oil muſt eſcape, and becauſe diſtilled waters evaporated to dryneſs leave no ſenſible portion of reſidue.

Common diſtillation of aromatic vegetables is a ſimple proceſs, but gives room for ſome nicety of management, particularly in the regulation of the heat and the quantity of water, which can only be learnt by experience. As an example common peppermint water may be given, and is thus made. Put a pound and a half of dry peppermint in a ſtill, cover it with water, put on the capital, luting the joints with wet bladder or paſted paper, bring the liquor to boil quickly, and keep it juſt boiling till about a gallon of water has run over. The reſidue in the ſtill is then thrown away as uſeleſs. The water that comes over firſt is ſomewhat turbid owing to the exceſs of eſſential oil that it contains, and in conſequence is by much the ſtrongeſt. By reſt it becomes clear, and a fine pellicle of oil riſes to the top.

The following circumſtances are chiefly obſervable in common diſtillation.

The ſubſtance from which the diſtillation is made in ſome caſes requires previous treatment, in others none. The petals of flowers, ſuch as roſes or jaſmine, may be uſed immediately or only after the gentleſt drying. The aromatic herbaceous vegetables, ſuch as peppermint, may be uſed indiſcriminately freſh or dry, obſerving that as the plant is much more watery when freſh than when dry, more water may be added in the diſtillation of the latter than of the former. Hard woods ſhould be raſped or bruiſed, and as they are leſs eaſily penetrated by the water they ſhould be macerated in it without heat for from one or two days to as many weeks, before diſtillation.

The quantity of water to be uſed varies much according to circumſtances. It ſhould be always ſo much as during the whole proceſs to cover all that part of the ſtill which is immediately over the fire, otherwiſe the vegetable matter will ſcorch and give a very diſagreeable burnt taſte and ſmell, or *empyreuma*, to the diſtilled liquor. On the other hand too much water makes the diſtilled liquor unneceſſarily dilute. In general, freſh vegetables require about thrice their weight of water, and when dry five or ſix times. The ſtill ſhould never be more than about three-fourths full, or even leſs when ſucculent vegetables are uſed, to prevent boiling over.

The management of the fire is of ſome conſequence, to prevent boiling over and empyreuma on the one hand, and on the other to give heat enough for extraction of the aromatic principle. Where a water bath is uſed (which however is tedious and ſeldom if ever neceſſary) all danger of exceſs of heat is avoided, but it is often requiſite to encreaſe the heat of the bath by adding ſalt to the water. When in diſtilling without a bath too much heat is uſed, there is danger either of blowing off the capital not without riſk to the bye-ſtander, when the liquor boils with extreme vehemence (which is particularly likely to occur when the ſtill is too full of bulky herbaceous vegetables that riſe in the capital and partly choak up the opening into the worm-pipe) or elſe the liquor boils over into the worm-pipe, and mixes a *decoction* of the vegetable with the diſtilled water. This is ſoon perceived by the condenſed liquor coming out at the bottom of the worm, not in a clear uniform ſtreamlet, but by guſhes and ſtarts with a guggling noiſe, and fouled or coloured. When this accident happens, the fire ſhould be entirely ſlacked, the capital taken off, the liquor already come over returned into the ſtill, and the diſtillation begun again with more care. When the ſtream of diſtilled water flows evenly, and the boiling liquor is heard to ſimmer moderately in the boiler the operator will know that the proceſs is going on properly.

The quantity of aromatic water to be obtained from a given weight of any vegetable cannot be laid down with accuracy, ſo as to obtain a liquor of uniform ſtrength as (independenly of any difference in conducting the operation) the ſeaſon of year, the length of drying, and other cauſes, will materially affect the intenſity of aroma in the vegetable. The taſte therefore is a better criterion to judge when to ſtop the proceſs, as the liquor will run nearly taſteleſs long before the water has all boiled away. Some advantage is gained by mixing all the diſtilled liquor together, as the firſt portion has generally rather more eſſential oil than it can retain, and the laſt portion has leſs.

Some other obſervations relative to the management of diſtillation will be mentioned under the article of OILS *Eſſential*, which are moſtly obtained by the ſame proceſs.

Diſtilled waters are generally ſuppoſed to be made much ſtronger by *cohobation*, or rediſtilling the ſame water from freſh materials. No very accurate experiments have been made on this ſubject, and it would appear that when water is the firſt time ſo ſuperſaturated with eſſential oil as to let go a portion by mere ſubſidence, no further proceſs can make it take up more. If ſo great an encreaſe of ſenſible and other properties is really produced by cohobation as is uſually allowed, it would render probable the old opinion of a *ſpiritus rector*, or a peculiar principle in which the active and odorant particles reſide, ſeparated from, and independent of the eſſential oil, and which is moſt largely diſengaged at the firſt impreſſion of heat, and ſoluble in water already ſaturated with eſſential oil.

Some pains have been taken by chemiſts to examine the properties of the diſtilled water of *inodorous* vegetables, and to endeavour to beſtow on it ſome medicinal qualities. The water diſtilled from theſe differs from common diſtilled water in poſſeſſing a faint and fugitive ſmell, in growing mouldy by keeping, eſpecially when expoſed to the air, and when a large quantity is evaporated, a minute portion of coloured extractive matter is left. This is found to contain a little nitre.[a] The diſtilled water of thoſe plants which have at the ſame time very active medicinal powers, and very feeble ſenſible qualities of ſmell or taſte (ſuch as the digitalis) deſerves further examination.

The greater number of thoſe liquors commonly called *Diſtilled Waters*, *Cordial Waters* (ſuch as of aniſeed, juniper, &c.) are prepared by the particular vegetable diſtilled with ardent ſpirit, more or leſs diluted, and belong to the ſubject of *diſtilled* SPIRITS.

DIURETIC *Salt*. See ACETITE *of Potaſh*.

DOCIMASIA, or *Docimaſtic Art* is applied to that part of chemiſtry which relates to the analyſis of minerals, and all operations in metallurgy.

[a] Delunel, An. Ch. tom. 38.

DOLOMITE[a]. *Chaux carbonatée aluminifère* Hauy.

Its colour is white with a slight tinge of grey or yellow. It occurs in mass or foliated; its lustre is glimmering, between pearly and vitreous: its texture is fine-granular; its fracture is compact uneven, passing into imperfectly lamellar. It breaks into irregular blunt-edged fragments. It is translucent on the edges, may be scratched by fluor-spar, and is often more or less friable between the fingers. Sp. gr. = 2.8. It is for the most part phosphorescent in the dark by percussion.

It is soluble in nitric acid slowly, and with but little effervescence. Its constituent parts according to Vauquelin[b] are

Carbonated Lime	52
Carbonated Magnesia	46.5
Oxyd of Iron .	0.5
——— Manganese	0.25
	99.25

It is found in various parts of the Alps, in beds alternating with micaceous schistus, and containing tremolite, orpiment, and cupreous pyrites.

The first analysis of this substance was made by Theod. Saussure, according to whom it consisted of about 88 per cent. of lime with an excess of carbonic acid, between 5 and 6 per cent. of alumine, and the rest magnesia and oxyd of iron: this however has been shown by Vauquelin to be wholly erroneous, and the dolomite will, no doubt, for the future, be considered as the massive variety of Bitterspath, which see.

DOME is a part of several chemical *Furnaces*. (See the Appendix.)

DRAGON'S BLOOD. *(Sanguis Draconis)*, is a resin that exudes from the bark of the *Pterecarpus Draco*, a large tree found in South America, and also from other vegetables, particularly the *Calamus Rotang* found abundantly in many parts of the East Indies.

The resin called dragon's blood is brought over sometimes in oblong pieces about the size of a small walnut, and sometimes in cakes. When good, it is uniform in texture, without smell or taste; breaks smooth and easily; has a very deep blood-red colour in mass, which lightens to a fine crimson when powdered, and readily burns when put to a candle with much flame, and a slight fragrant smell like styrax. Dragon's blood when genuine is nearly if not absolutely insoluble in water, but readily dissolves in alcohol, giving it a very intense red colour. Water makes this solution turbid. This resin is in some degree soluble in fixed oils, giving them a dull red colour.

Dragon's blood is used pretty considerably in many coloured varnishes and lacquers, often to give a mahogany colour to white wood, or when mixed in small portion with the gamboge yellow it much improves the tint, rendering it deeper and richer. It is a little employed in medicine.

DRYING *Oil* is oil prepared by boiling with litharge, and is the basis of a vast number of paints and varnishes. See Oils *Fixed*.

DUCTILITY. *Geschweidikeit*, Germ. This term is applied to expres that extensibility and cohesion of particles which enables a metal to be drawn out into wire without breaking. There is but a slight shade of difference between this property and that of malleability.

DULCIFICATION. *Versüssung*, Germ. Is a term not very accurately defined, and little used. It is generally employed to expres the rendering mild, or diminishing the corrosive qualities of acids or alkalies by uniting them with some other substance, but not so as to neutralize them. Thus alkalies might be said to be dulcified when converted into soap; and the strong acids are actually said to be *dulcified* when chemically combined with spirit of wine. Thus we have dulcified spirits of vitriol, dulcified spirit of nitre, &c.

DYEING. *The Art of. L'Art de la Teinture*, Fr. *Farbekunst*, Germ.

The object of this antient and truly chemical art is to fix uniformly, and more or less permanently, certain colouring matters into the fibres of wool, linen, cotton, silk, and other filamentous substances.

The first explanation offered of the theory of dyeing was purely mechanical. According to Hellot, an excellent observer and an acute reasoner, the saline substances employed in dyeing serve to open and enlarge the pores of the fibres to be dyed, the colouring matter is then deposited in these pores, after which, the natural elasticity of the fibre returning, shuts in the particles of colouring matter, and the salts solidifying over them serve as a kind of cement to keep them in their place.[c]

Many and insuperable objections however have been brought against this and similar mechanical theories of dyeing, which it is not necessary here to detail.

It is particularly incompetent to explain the great difference between animal and vegetable

[a] Hauy. [b] Journ. des Mines, xvi. p. 77. [c] Mem. de l'Acad. 1740 and 1741.

matter in abſorbing and retaining colour, and the uſe of mordants or intermedes as a bond of union between the colour and the fibre to be dyed. Bergman appears to have been the firſt whoſe eminent ſagacity ſuggeſted the idea that chemical affinity was the great agent in theſe operations, and every ſubſequent reſearch more and more confirms this opinion.

A detailed account of all the proceſſes of dyeing would of itſelf fill a volume: in this place therefore all that can be done will be to give a very ſhort view of the leading facts and operations, particularly as connected with general chemiſtry, and refer the reader to ſome of the moſt valuable written documents, particularly to Berthollet's admirably ſcientific and philoſophical view of the ſubject.[b]

The ſubſtances commonly dyed are either of animal or vegetable origin. To the former belong wool, ſilk, hair, leather, and ſkin of all kinds; to the latter, cotton, flax and hemp. The particular chemical analyſis and properties of theſe ſubſtances, as far as they have been examined, will be deſcribed under the reſpective articles. A moſt important and eſſential difference exiſts between the affinity for colouring matter poſſeſſed by theſe ſubſtances, ſo that a proceſs which perfectly ſucceeds in dyeing wool (for example) may have no effect upon cotton, neither is there any agreement in the quantity of colouring ingredient neceſſary to dye each ſtuff.

A ſimple experiment of Dufay's proves this. He had a piece of cloth woven, of which the warp was wool and the woof cotton, this was fulled that each ſubſtance might undergo exactly the ſame preparation, and then paſſed through a ſcarlet vat. The wool only took the colour, but the cotton remained white after rincing. With regard to quantity of colour, it is found that ſilk takes twice as much cochineal to dye it as wool does. The different force of affinity between different fibres and colouring matter is alſo ſhewn by the more or leſs perfect manner in which they exhauſt a coloured bath; thus, as Bergman obſerves, wool dyed in a weak ſolution of ſulphat of indigo entirely abſorbs the dye and leaves the ſolution colourleſs, whereas ſilk can only partially rob the ſulphuric acid of the colouring matter. Generally ſpeaking, wool has the ſtrongeſt affinity for colour, taking it more eaſily, and retaining it more firmly; ſilk and other animal matters come next to wool, cotton next, and hemp and flax laſt; but this is to be underſtood with great latitude, nor does it always happen that ſubſtances which take colour the eaſieſt, retain it the longeſt, beſides that the previous preparation is not the ſame, and hence the compariſon is not altogether accurate.

No exact explanation can be given of the different affinity for colour in different ſubſtances, except that the analyſis of vegetable and animal matters ſhews a moſt eſſential difference in their component parts, and their habitudes with chemical reagents. It is on this account too that the preparation which each ſubſtance receives previouſly to being dyed ſo much varies. Animal matter, eſpecially wool, when immerſed in cauſtic alkali has its fibre immediately relaxed, becomes clammy, loſes its natural toughneſs and elaſticity, and at laſt is entirely diſſolved into a ſoapy compound. Vegetable fibre on the other hand reſiſts alkalies much longer, and is not eaſily diſſolved; and hence in the previous cleanſing and fulling of wool, alkalies are ſcarcely admiſſible, or muſt be uſed with extreme caution, whereas they may be employed with ſafety in the preparation of cotton and linen. Animal fibre is alſo much more eaſily affected by acids.

The ſimple colours employed in dyeing are chiefly of animal or vegetable origin. The number of poſſible dyes is almoſt equal to that of the vegetable or inſect tribes on the face of the earth, for almoſt all of theſe will make a coloured decoction with water, which is capable of tinging cloth immerſed in it. Hence the variety of native dyes from indigenous plants uſed in different parts of the globe by every nation, ſavage or civilized. A very few, however, are employed in the regular manufactories of European nations, being ſuch as are obtained in the moſt abundance from countries where they form valuable articles of commerce, and whoſe qualities are minutely known by long and accurate obſervation.

Of the great variety of known dyes, ſome (though comparatively but few) may be applied to animal or vegetable fibre without any other preparation than that of cleanſing the ſtuff, and immerſing it in a decoction or infuſion of the dye for a ſufficient time. The colouring matter then unites with the fibre of the cloth with a greater or leſs degree of force, ſo as ſometimes permanently to reſiſt the effect of waſhing, and the bleaching power of the ſun and air, ſometimes partially, ſometimes ſcarcely at all. On the other hand the greater number of dyes have naturally only a very feeble affinity for fibre, (though never in the ſame degree for animal and vegetable) and therefore, when applied without

[b] Elements de Teinture, ſecond edit.

addition, they are deſtroyed very ſpeedily; but the ingenuity of man has diſcovered that they may be made to unite with fibre much more durably by the intermede of ſome other ſubſtance (generally a ſalt with an alkaline, earthy, or metallic baſis) which poſſeſſes a very ſtrong affinity both with fibre and with colouring matter, and hence ſerves to bind the one to the other. Theſe intermedes are called *Mordants* (a term derived from an erroneous theory now abandoned) and the uſual practice is firſt to ſteep the cloth or fibre in the mordant, and afterwards in the dye.

The dyes that cannot be fixed into the ſtuff without mordants may be termed (with Dr. Bancroft) *adjective* colours; thoſe in which mordants are of no uſe may be called *ſubſtantive* colours. Madder is an adjective colour, ſince it is rendered much more durable by the intermede of alum, or of many other ſalts than when uſed alone. Indigo is a ſubſtantive colour, ſince its durability is not encreaſed by any intermede whatever.

Another important difference in the nature of dyes is in the degree of permanence of tint, which certainly in part depends on the force of affinity with which it unites to the fibre, and partly on the intimate nature of the colouring matter, and its ſuſceptibility of decompoſition by light, air, moiſture, and alſo by alkalies, ſoaps, and other ſubſtances employed in the common uſes of dyed ſtuffs. The permanency of colour has no neceſſary connexion with the mode in which it is united to the ſubſtances dyed, for among the ſubſtantive as well as the adjective colours ſome are very permanent, others very fugitive. For example, of the ſubſtantive colours (or thoſe which unite as ſtrongly to cloth without, as with mordants) *Indigo* is very permanent, reſiſting the ſun, air, waſhing with ſoap, and moſt chemical agents: the oriental *Henne*, which is a fine orange red, long reſiſts the ſun and air, but is altered and deſtroyed by ſoap: *Archil*, and other of the purple lichens, is inſtantly altered by ſoap, and is ſoon changed by the light and air, ſo as only to give a very fugitive but beautiful gloſs. Of the adjective colours *Madder* is one of the moſt permanent that is known, retaining its body of colour (when well applied) under almoſt every circumſtance. *Cochineal* on wool is nearly equally faſt or permanent, but on cotton much leſs ſo, *Brazil Wood* fades much ſooner than the laſt, whatever mordant be applied.

The ſelection and right application of mordants is of infinite conſequence in dyeing, and it is this ſubject, with its various modifications that forms the truly ſcientific part of this beautiful art. Linen or cotton requires a different mordant from wool or ſilk, ſome colours adhere only to a particular mordant, the order of application, the ſtrength, and many other ſmaller circumſtances, all of which materially affect the beauty and durability of the colour, and the texture, of the cloth, muſt be attended to by the artiſt.

Some ſimple experiments related by Dr. Bancroft,* and which are readily repeated, well illuſtrate the action of mordants. A piece of cotton was impreſſed with various figures with a mordant of acetited alumine, and when dry was rinced and cleanſed in the uſual way of calico printing. It was then dyed in an infuſion of ſaffron and came out uniformly yellow, but on expoſure to air the whole became white. Hence it is ſhewn both that the colouring matter of ſaffron has no ſtrong affinity with cotton, and that alumine has no power of fixing it, and hence is uſeleſs as a mordant. The ſame piece was then dyed with a decoction of Brazil wood, and the whole came out coloured, but the figures printed with the aluminous ſolution were of a fine crimſon, whereas the ground was only faintly tinged. On expoſure to the ſun and air for two days the ground ſoon became white, and the figures alſo were faded, and in eight days the crimſon of the latter, which had been gradually diminiſhing, was no longer viſible. This ſecond experiment ſhews that acetited alumine is a powerful mordant for Brazil wood, but ſtill not ſufficient finally to fix its colour.

The ſame piece was then dyed with a decoction of madder, and the whole came out coloured, but the figures deeper than the ground. On waſhing with bran and water, and expoſure to ſun and air, the ground became white, but the figures retained all their body and brightneſs of colour, and this time the dye was permanent, ſhewing in a very ſtriking manner the ſtrong affinity both of the alumine for the cotton ſo as to remain fixed in its fibres during three ſucceſſive operations, and of the alumine for the madder colour ſo as to retain it permanently in ſpite of the waſhings and bleaching which entirely deſtroyed the dye of the ground.

Mordants not only fix colouring matter, but moſt commonly they in ſome degree alter the natural hue. Thus in the inſtance above-mentioned the aluminous mordant changed the dull

* Experimental Reſearches on permanent Colours.

red of madder to a bright crimſon; the ſolutions of tin not only fix the colour of cochineal in wool, but change it from crimſon to a bright ſcarlet: the ſalts of iron which are powerful mordants, always alter the colour of dyes, changing the yellow of weld to olive-brown, drab, or lead-colour according to circumſtances, the red of madder to a violet brown, and, as is well known, ſtriking a bluiſh-black whenever the gallic acid is preſent. Hence a great advantage is moſt ingeniouſly made of mixing different kinds of mordants to produce varieties of ſhade; thus a mixture of the iron and aluminous mordant will produce with madder all the ſhades of flea-colour, purple and violet; with weld, brown and olive green, and the like, ſo that with no more than three or four colouring materials an almoſt infinite variety of dyes may be produced by a due ſelection and mixture of the various mordants.

Two important and diſtinct manufactures belong to the ſubject of dyeing, the one is *dyeing* properly ſo called, or the art of giving an uniform colour to an entire piece of ſtuff: the other is topical dyeing, or the art of fixing various coloured patterns on an uniform ground, which, from its being chiefly and originally employed on cotton or calico, is called *Calico-printing*. The baſis of each art, as far as relates to the chemical action of the fibres of the ſtuff upon the different dyes and their mordants, is preciſely the ſame, and in general the materials employed are nearly the ſame, but the manipulations and particular mode of application widely differ. A few of the principal proceſſes of general dyeing will firſt be deſcribed, after which a ſhort notice will be taken of calico-printing.

The proceſs of dyeing in the piece conſiſts of a few ſimple operations repeated more or leſs often according to circumſtances, with many minute variations in the temperature, time of immerſion, and the like, according to the nature of the ſtuff and the colour to be given, by rules which experience alone can teach.

The following is a ſhort ſketch of the mode of dyeing the principal colours, chiefly taken from Berthollet, Lewis, Bancroft, Hellot, and ſome other authorities; but it ſhould be added that the variety in the proceſſes actually uſed is almoſt endleſs, almoſt every manufacturer having his particular receipt, in which ſlight variations in the quantity or quality of ingredients, the time or order of application and other minute circumſtances, are found to render the colour ſomewhat more or leſs full, durable, gloſſy, uniform, and the like.

Of Blacks.

There are a few native vegetable juices that produce durable *ſubſtantive* blacks, or ſuch as can be fixed at once on cloth without any previous preparation. Of this kind is the *Anacardium orientale*, a kind of nut, containing between the inner and outer ſhell a fungous ſubſtance filled with a viſcous fluid in ſmall quantity. This juice rubbed on linen and cotton gives a reddiſh brown ſtain, which by expoſure to air deepens to a full black that is quite permanent. It is ſaid to be uſed in India for marking linen and cotton cloths, and hence is called the *Marking Nut*. The Weſt India caſhew nut is of a ſimilar nature with the Eaſt Indian *anacardium*, but the colour is not ſo deep. The anacardium would be highly valuable if it could be collected in quantity, particularly for linen and cotton, but is only uſed very partially in the countries of which it is a native.

Several other native vegetable juices yield permanent ſubſtantive blacks, ſuch as the American *Rhus Toxicodendron* or *Poiſon Aſh*, and other tropical plants, but none of theſe are uſed in Europe.

The black commonly given to all kinds of ſtuff is that which is produced by ſome vegetable aſtringent, particularly galls, with the ſalts of iron, but many circumſtances muſt be obſerved in order to produce a full and good colour. Wool takes this kind of black with much more eaſe than linen or cotton, and is dyed in the following manner.

The woollen cloth is firſt dyed of a very deep blue with indigo, to give a fuller body of colour. The black is then given by aſtringents and iron, of which the following is Hellot's elaborate and excellent proceſs.

For every 50 lb. of cloth take 8 lb. of logwood and as much galls, both bruiſed or powdered, tie them looſely in a bag and boil in a moderate fized copper for about twelve hours with ſufficient water. Put one-third of this decoction with a pound of verdigris into another copper, and ſoak the cloth in it for two hours, keeping the liquor ſcalding hot but not boiling. Take out the cloth, add to the ſame copper another third of the firſt decoction, with 4 lb. of vitriol or ſulphat of iron, and bring again to a ſcalding heat, and ſoak the cloth in it for an hour, ſtirring it well all the time. Then take out the cloth and add the remaining third of the decoction with 8 or 10 lb. of ſumach, boil the whole,

lower the heat with a little cold water, add a pound more of vitriol, and return the cloth for an hour longer. The cloth is then waſhed and aired again, and returned to the bath for an hour, after which it is well waſhed in running water and fulled. It is laſtly paſſed through a yellow bath of weld for a ſhort time, to give a higher gloſs and ſoftneſs to the black. It is then waſhed and dried in the uſual manner.

The common blacks however are given in a much ſimpler manner, the ſtuff (previouſly dyed blue) being firſt ſoaked in a bath of galls and boiled for two hours, and then paſſed through another bath of logwood and vitriol at a ſcalding heat for as much longer, after which it is waſhed and fulled.

Several obſervations are to be made on this proceſs.

The previous dyeing blue is not in the leaſt neceſſary to enable the cloth to take the black afterwards, but it is found to be of great ſervice in giving body to the colour, and is never omitted in the fineſt blacks. The indigo blue is the beſt preparation for black, being a deep heavy dye and aſſimilates well with perfect black. When this proves too expenſive for the ſtuff, it is ſometimes prepared of a buff or fawn colour with walnut huſks inſtead of blue.

Black is never given by a ſingle operation: that is, the ſtuff is firſt impregnated with the galls or other aſtringents either at once or elſe by ſeveral proceſſes, and afterwards paſſed into the vitriol bath. The colour is thus rendered much faſter than if the whole ingredients were firſt mixed. A certain proportion muſt be obſerved between the aſtringent vegetables (of which kind are the galls, logwood and ſumach) and the ſalt of iron, for if the former are in too great a quantity, the black is again degraded towards a grey ruſty hue. Too long a maceration of the cloth has the ſame effect, as Lewis has well obſerved, [d] and Berthollet remarks that a ruſty colour is given to the fineſt black by being paſſed through a freſh bath of galls. The black colour is not entirely brought out till after the cloth is expoſed to the air, an effect ſimilar to the well-known deepening of the colour of pale ink ſome hours after it is uſed.

Logwood does more than merely add to the quantity of vegetable aſtringent, for it contributes much to the depth of colour and counteracts the browniſh ruſt tinge which galls and iron alone are apt to give. Where the cloth is not previouſly blued, logwood is particularly neceſſary. A very fine black is produced on blue cloth, according to Lewis, by 5 lb. of vitriol, 5 lb. of galls, and 30 lb. of logwood.

The verdigris alſo has a good effect in improving the colour, but it is not exactly known how it acts.

In Hellot's proceſs the cloth already black is finiſhed by a yellow weld bath. Madder has alſo been much uſed in the ſame way, and is ſuppoſed to give a velvety ſoftneſs to the colour. The uſe of any of theſe finiſhing tints is however much diſputed, and is in a good meaſure diſcontinued.

Wool is dyed black nearly in the ſame way as woollen cloth. The natural greaſe of the wool is firſt removed by boiling in a bath of ſtale urine and water, after which the wool is dyed blue and black nearly in the way abovementioned.

Some variety of the above proceſſes is required to give a black dye to ſilk. Raw ſilk in the ſtate in which it is ſpun from the coccoons, is covered with a natural kind of gum or varniſh, which gives it its beautiful orange yellow colour, and alſo a degree of ſtiffneſs and elaſticity which is detrimental to the manufacture and muſt be firſt removed. This is done by boiling it in water for four or five hours with a fifth of its weight of fine white ſoap which diſſolves this gummy matter. The ſilk loſes about a fourth of its weight in this proceſs. To dye it black it is then boiled three or four hours with about three-quarters of its weight of galls, and ſuffered to remain without boiling for about a day, more or leſs according to the kind of manufacture for which it is intended. It is then blackened in a bath of ſulphat of iron, iron filings, and cherry-tree gum, with many manipulations too numerous to be here deſcribed. Silk is ſeldom if ever previouſly blued, as wool is, but ſometimes a root or fawn-coloured ground is given by walnut huſks. Silk requires many more dippings and alternate ſoakings with galls and iron than wool does, to produce a full good colour, and the quantity of galls required differs moſt remarkably, five or ſix pounds being ſufficient for a hundred pounds of wool, but upwards of fifty for the ſame weight of ſilk. Hence the dyeing of ſilk is much more expenſive.

Hats are dyed with only a ſingle bath of the mixed ingredients. The bath is made of 100lb. of logwood, [e] 12 lb. of gum, and 6 lb. of galls boiled for ſome hours with water, after which 6 lb. of verdigris and 10 lb. of ſulphat of iron are added, and the liquor kept juſt of a ſcalding

[d] Commerce of the Arts. [e] Lewis.

heat. Ten or twelve dozen of hats are immerſed by a proper contrivance into the liquid for about an hour and a half, then taken out and aired, and another ſet immediately immerſed for the like time. Each ſet is dipped and aired alternately for eight times, the bath being occaſionally refreſhed by more of the ingredients. The verdigris is found by experience to be eſſential to the beauty of the dye.

It is a much more difficult operation to fix a permanent black on linen and cotton, which will ſtand waſhing with ſoap and long expoſure to the air. The proceſſes that ſucceed on wool do not anſwer well here, the black being very liable to degenerate to a ruſty brown.

Linen or linen thread is generally firſt blued with indigo and then receives a mordant of alum, after which it is paſſed through a bath of galls or logwood, or alder, and blackened with the iron ſolution, for which a variety of proceſſes are given.

A fine durable black on cotton is of ſtill more conſequence in the preſent immenſe trade of printed cottons than on linen, and much pains has been taken to equal the excellent faſt black given to cotton goods in the Eaſt Indies, the proceſs for which is not known, unleſs it be with the anacardium or other native vegetable juices. For many years a kind of acetite of iron has been uſed very largely in England as a ſubſtitute for the ſulphat in the black dye, and alſo partly as a ſubſtantive colour, by which alone many uſeful ſhades of buff, nankeen, and other dyes are given. This acetite is made by macerating refuſe pieces of iron in ſour beer, vinegar, elder-berries, and other ſubſtances that afford the vegetable acids and produce in time a very ſtrong uncryſtallizable high-coloured ſolution. Of late years too the pyroligneous acid (obtained from the diſtillation of wood in making the beſt charcoal for gunpowder) and the empyreumatic acid of tar have been uſed very extenſively in calico-printing for ſimilar purpoſes and with very compleat ſucceſs, but the preciſe mode of application is kept ſecret. It appears that galls or ſimilar vegetable matter are not required with this preparation, but the place is ſupplied with madder, which with a deep iron ground may be made to give a very dark purple-brown hardly diſtinguiſhable from black.

Since cotton and linen, which are of vegetable origin, have naturally leſs affinity with colouring matter than wool and animal matters, dyers have been in the habit in many parts of the world of impregnating linen and eſpecially cotton with many compound mordants, the united effect of which is certainly in many inſtances to enable them to take and retain colours with much more perfection than any ſimpler proceſs could obtain. Sometimes theſe mordants are animal glues, animal oils, dung, &c. and it has been very happily conjectured that the great advantage of theſe is in ſome degree to *animalize* the vegetable fibre, as it were, and thus in point of affinity with colouring matter to bring it more on a level with wool, ſilk, and the natural animal fibres. The fine turkey red of madder fixed on cotton by a very complicated proceſs, is a ſtriking inſtance of the uſe of theſe compound mordants, as will be afterwards mentioned. The following proceſs for dyeing linen and cotton of a fine durable black is given by Mr. Vogler, an eminent practical artiſt, in which animal glue is uſed as a mordant, together with a ſolution of lead, which laſt ſeems to have a ſtrong affinity for the materials of which the black dye is compoſed.

Mix in a large bottle* a quart of ſoft water with 2 or 2½ ounces of common aquafortis, and throw in from 2 to 3 ounces of litharge. Set the bottle in a warm place frequently ſhaking it, till a ſolution is made, which when uſed ſhould be poured off clear from the ſediment. In this dilute nitrated lead firſt ſoak the linen or cotton thread (without heat) for ten or twelve hours, then take it out, waſh it and wring it well. Next dip the thread into a moderately ſtrong warm glue water, wring it out but do not waſh it, and let it dry in the ſhade. Next make a decoction of ¾ of an ounce of galls in a quart of water, and when they have boiled for ten minutes throw in ¾ of an ounce of ſalt. Then ſoak the thread therein for ſeven or eight minutes with a boiling heat, waſh, wring and dry as before. The thread has now a dark yellowiſh grey colour. Afterwards diſſolve ¾ of an ounce of ſulphat of iron with as much ſalt in a quart of clean hot water, ſoak the thread therein for eight or ten hours, after which waſh and dry. The colour is now black but is much improved by the following operations. Boil ¾ of an ounce of logwood in a quart of water for ten minutes, after which add a quarter of an ounce of ſtarch, and when well mixed put in the blackened thread or ſtuff, and boil for 7 or 8 minutes, after which waſh it in cold water and dry. Laſtly, the colour, which is much improved by the foregoing operation is fixed by the following. Make a bath of one

* Crell's Annals or Repertory, vol. 8.

ounce of bruiſed galls and a quart of pretty ſtrong glue, and when it has boiled for 10 minutes add one ounce of vitriol of iron, and allow the whole to cool with frequent ſtirring. Then ſoak the thread for an hour in the liquor, after which wring it out and dry it in the ſhade. The dye is then compleat. Though the above proceſs includes many operations it does not appear needleſsly complex, but on the contrary is very judicious, and agreeable to the long eſtabliſhed practice of the art. Cloth of cotton or linen may be dyed in this way, according to the author, as well as thread.

Of Grey.

Many of the varieties of grey, iron-grey, ſlate colour, &c. are given by proceſſes in general ſimilar to thoſe for black, but with ſmaller quantities of the ingredients, and eſpecially a ſhorter time of immerſion. They are often finiſhed with a weak bath of weld, cochineal, Brazil wood, and other livelier colours to give ſome particular tints.

Of Blue.

The principal material for this moſt important colour is indigo, a ſingular vegetable preparation produced by the fermentation of the leaves of a ſmall plant, the *Indigofera Tinctoria*, and one or two varieties of the ſame genus, cultivated abundantly in many tropical countries, particularly in Mexico and other parts of Spaniſh America, and of late years very largely in the Britiſh Eaſt Indies.

Many important chemical facts are connected with the preparation of this colouring matter, which, with the analyſis and fuller account of the methods of ſolution for the purpoſe of dyeing will be referred to the article *Indigo*. It will be ſufficient to obſerve in this place that indigo is brought over in the form of cubical cakes or lumps, which (when the article is of the beſt kind) are of a very deep blue colour almoſt black in maſs, very light, breaking ſhort and eaſily reduced to powder; when rubbed with the nail ſhewing a poliſhed copper-coloured ſtreak, and of a peculiar ſmell, which particularly ſhews itſelf when in ſolution.

Indigo is ſoluble of itſelf in ſcarcely any known menſtruum except the ſtronger acids; water, alkalies, ſpirit of wine, &c. added ſingly having no action on it whatever. The reaſon of this great inſolubility appears from multiplied experiments to conſiſt in the high degree of oxygenation in which blue indigo in its common ſtate exiſts. That the blue colour depends on the action of the air is obvious from the circumſtance, that in the preparation of this dye the colour of the fermented plant is at firſt green, but by expoſure to air it takes the deep and permanent blue, for which it is much valued. Other experiments which will be mentioned under this article make it appear that the change from green to blue is owing to this cauſe.

In order to render indigo ſoluble for the purpoſes of dyeing a faſt colour, a complicated proceſs is requiſite. Firſt, ſome ſubſtance muſt be added which is capable of partially deoxygenating indigo, or of reducing it to a ſtate ſomewhat ſimilar to the recent green pulp of the indigo while under manufacture; and next, a liquid muſt be added capable of diſſolving the deoxygenated indigo, that it may be applied to the fibres of the ſtuff immerſed in it. The former object is fulfilled by a great variety of ſubſtances, ſo different in nature, that it is hardly to be conceived that they can have any other property in common than that to which their utility is attributed, namely, that of depriving indigo of its oxygen.

The additions actually employed for this purpoſe, or found by experiment to be capable of being ſo uſed, are other dyeing matters, ſuch as madder or weld, vegetable mucilaginous ſubſtances, ſuch as ſugar or gum,[s] and alſo many metallic *ſub-oxyds*, or metals only partially combined with oxygen and capable of abſorbing from the indigo that additional quantity of this principle which is requiſite to complete ſaturation. The ſub-oxyd of iron is chiefly uſed for this purpoſe, and is made extemporaneouſly by mixing lime and ſulphat of iron; and as a proof of the neceſſity of uſing *ſub-oxyd*, and not a perfect oxyd, it may be added that the red perfect oxyd of the ſame metal has no effect whatever in bringing indigo to a ſoluble ſtate. Dr. Bancroft alſo has found the ſub-oxyd of tin equally beneficial. The ſulphuret of arſenic or orpiment is alſo commonly uſed for the ſame purpoſe.

The indigo thus deoxygenated is now ſoluble in the alkalies or in lime-water, which are the ſolvents actually employed in the compoſition of the indigo vat.

Indigo is a *ſubſtantive* colour, or one that requires no mordant to be previouſly united with the ſtuff to be dyed. It is alſo one of the faſteſt colours known, but to render it permanent, it muſt be preſented to the fibres of the cloth in its green deoxygenated ſtate. Hence it is that cloth when it comes out of the indigo vat is

[s] Bancroft.

always of a deep green, but by expoſure to air it ſoon changes to a fine deep blue. This change of colour of the ſolution of indigo from green (or, if much alkali has been uſed, yellowiſh green) to blue, forms a very entertaining experiment in the ſmall way. The ſame change is conſtantly going on upon the ſurfaces of indigo vats, which, being in contact with air, are always covered with a fine variegated green and copper-coloured ſcum that is perpetually paſſing to blue, unleſs ſtirred in and mixed with the maſs below.

This conſtant change in the nature of the indigo demands an equally conſtant attention to the ſtate of the vat on the part of the workman, to keep the liquor at the proper point of oxygenation; for when the blue colour is regenerated, the indigo again partly ſeparates from the lime or alkaline ſolvent, or remains only ſuſpended in it as a fine impalpable powder which will not adhere to cloth with any permanence. A freſh addition of the deoxydating materials alſo becomes from time to time neceſſary; but again, too great a quantity of this and of the lime or alkali is equally detrimental, and ſo far alters the nature of the indigo that it will no longer change to blue by air, but remains of a ruſty yellowiſh green.

Woad, which is a fecula or dried pulp made of the fermented leaves and ſtem of the *Iſatis Tinctoria*, and in nature not unlike indigo, is commonly uſed along with indigo in the dyeing of woollen. Woad is never employed alone, for the blue colour which it gives, though full-bodied and very permanent, is not ſufficiently bright and gloſſy. In its nature and affinities for oxygen it appears conſiderably to reſemble indigo.

The bath in which wool is dyed blue is not a copper boiler as is the caſe with other dyes, but is a large wooden vat generally ſunk in the ground fitted with a cover to protect it from the draught of external air, and to preſerve the temperature more uniform. The colour is ſometimes procured from indigo alone, ſometimes from a mixture of indigo and woad. The latter is prepared in the following way.[h]

Two hundred parts of woad broken ſmall are firſt thrown into the vat, to which is then added a hot decoction of 15 parts of weld, as much madder, and a baſket of bran all boiled in a ſeparate veſſel with water enough to fill the wooden vat. This is allowed to remain at reſt for ſix hours, when the whole is well ſtirred together and again let to reſt. A kind of fermentation is thus produced in the vat, attended with very ſtrong acrid vapours, owing to the beginning decompoſition of the woad. After a ſufficient time (during which the ſtirring is often repeated) 4 parts of lime are added which turns the vat of a black colour, and makes the fumes ſtill more acrid. Immediately afterwards from 5 to 15 parts of indigo (more or leſs according to the depth of colour to be dyed) mixed up with water into a cream-like fluid are poured in, and the whole ſtirred and covered. The diſoxygenation of the indigo is effected by the action of all the vegetable matter already in the vat, and when thus altered it is diſſolved by the lime. The ſigns of the ſolution of the indigo are the riſing of a blue copper-coloured and variegated ſcum, and the liquor beneath becoming of a bright green.

Before the cloth is put into the vat, it is wetted with clear hot water and wrung out. The time of remaining in the vat depends on the depth of colour wanted and on other circumſtances.

It comes out green, as already mentioned, but the colour changes to blue by expoſure to air. It is then thoroughly waſhed to diſcharge all the colouring matter that is not fixed, and dried in the field.

Dr. Bancroft thinks (and with ſome reaſon) that the weld and madder added to this vat have little other effect than to ſupply vegetable matter for the fermentation which is to diſoxygenate the indigo, and hence that inſtead of theſe expenſive ingredients, any herbs, or a greater quantity of bran, or coarſe ſugar, or many other cheaper materials might be ſubſtituted.

A richer blue bath, that gives a finer and ſofter colour (but is more expenſive on account of indigo alone ſupplying the blue colour) is made by boiling in a copper with ſufficient water, 9 parts of pearlaſh, with as much bran and 1 part of madder, after which 9 parts of indigo ground up with a little water are added, and a gentle heat kept up for about forty-eight hours, ſtirring the whole well together three or four times during the ſolution. In this caſe the alkali is the ſolvent of the indigo when deoxygenated by the bran and the madder.

In other indigo baths the ammonia contained in ſtale urine is the ſolvent of the colouring matter, and the deoxygenating matters are madder and tartar. The variety is endleſs of combinations thus afforded by the uſe of a vaſt

[h] Bertholler.

number of vegetable matters, with lime or any of the alkalies.

Silk is dyed in a similar indigo vat with the foregoing, and without woad. For the very deep colours however it is found neceſſary to prepare the ſilk with a high purple from archil.

Metallic ſub-oxyds and ſulphurets were mentioned to be equally powerful in deoxygenating indigo, with vegetable matters, and to be employed accordingly. This chiefly takes place in preparing the indigo vats for cotton and linen. A very ſimple and efficacious mode of compoſing this kind of blue vat is to mix together one part of indigo, 2 parts of ſulphat of iron, and 2 of lime with ſufficient water in a vat, to ſtir them together very well for a conſiderable time, and then ſuffer them to remain two days at reſt. In this caſe part of the lime firſt decompoſes the ſulphat of iron, ſeparating the ſub-oxyd of iron, which then acts on the indigo and brings it to the ſtate of the green-yellow or deoxygenated indigo, at which time it becomes ſoluble in the remainder of the lime. This vat therefore conſiſts of a ſolution of deoxygenated indigo by lime, mixed with ſome ſulphat of lime (ariſing from the decompoſition above mentioned) and at the bottom is a ſediment of the oxyd of iron, with any undiſſolved lime or regenerated blue indigo that may be contained. The cotton comes out of the vat green as in the former caſe, and turns blue by expoſure to air. It is the conſtant practice after the cotton is dyed to paſs it through a ciſtern containing cold water with a ſmall proportion of ſulphuric acid. This is found to heighten the colour, and is of further uſe in diſſolving out any adhering lime or ſulphat of lime which would give a harſhneſs to the ſtuff and impair the luſtre.

Alkalies are alſo frequently uſed inſtead of lime in the above vat. Their effect is preciſely the ſame as that of the lime, only being themſelves much more ſoluble in water than lime, they will bear a much larger proportion of indigo, and of courſe will form a much deeper and richer dye.

The indigo rapidly *regenerates* or recovers its oxygen (and with it its blue colour) at the ſurface of all theſe ſolutions, and in ſo doing it ſeparates from the alkali or lime-water which held it diſſolved, and partly ſinks to the bottom, partly remains entangled in the ſcum. Hence the uſe of the occaſional ſtirrings to mix the regenerated indigo with the other materials, and again diſſolve it. Frequent additions are alſo uſed of the deoxygenating and diſſolving ſubſtances to refreſh the vat when long expoſed to air, and bring it back to the proper ſtate for dyeing.

It is remarkable that the ſalts of copper are found by conſtant experience to have a totally oppoſite effect on indigo from the ſalts of iron, the former being obſerved not only to have no effect in rendering indigo ſoluble, but even to prevent the operation of the ſub-oxyds of iron, and to haſten the regeneration of diſſolved indigo. This is ſuppoſed to be the reaſon why cottons, firſt ſoaked in ſulphat of copper, and then paſſed through a very weak indigo vat, extract at once all the colour, the copper determining the immediate ſeparation of the indigo.

Orpiment or ſulphuret of arſenic is chiefly uſed in preparing the indigo ſolution for topical application in calico-printing. Mr. Hauſſman mixes for this purpoſe 25 gallons of water with 10 pounds of indigo (more or leſs according to its quality), to which is added 30 lb. of good pearlaſh, 12 lb. of lime, and 12 lb. of orpiment. The whole is boiled for a ſufficient time with ſtirring, and forms a very ſtrong yellow liquid ſolution, which turns blue by expoſure to air. For calico-printing it is thickened either with gum ſenegal or with ſtarch to the conſiſtence of a jelly, and when ſtrongly impreſſed on cotton it forms durable blue figures. The extreme inconvenience of this and all other ſolutions of indigo in lime or alkalies, is the impoſſibility of preventing the perpetual regeneration of the indigo before the whole is uſed; and as all the colour prematurely regenerated is readily waſhed away in the after proceſſes, it becomes extremely difficult to maintain an uniform ſhade of blue through the pattern of a whole piece of cloth. The gum or paſte are of further uſe in retarding this premature change of the indigo.

According to Profeſſor Pallas[k], cotton and ſilk are dyed blue at Aſtracan, by a bath very ſimilar to the ſimpleſt indigo vat for wool, the deoxygenating ſubſtance being honey and the ſolvent of the indigo being ſoda.

The proportions are 2 lb. of indigo, 5 lb. of carbonat of ſoda, 2 lb. of lime, and 1 lb. of clarified honey. Theſe are put with ſufficient water into large earthen jars ſet in brick work over a fire, which will bear a boiling heat, and are heated with frequent ſtirring, till the indigo is diſſolved.

Saxon Blue is the name given to a totally different preparation of indigo from thoſe hitherto

[k] Ph. Mag. vol. 1.

mentioned, and is made by digeſting this colouring matter for above twenty-four hours, with a gentle heat, in about four times its weight of ſtrong ſulphuric acid. This acid (which thus concentrated, and with the aſſiſtance of heat, would charr and deſtroy moſt vegetable matters) produces but little apparent alteration on indigo, but diſſolves it into a fluid of an inky blackneſs when undiluted, but when largely mixed with water, it produces a very beautiful tranſparent blue liquor, of a brighter colour than the alkaline ſolutions of indigo, and capable of giving very fine dyes to cloth, ſilk, or cotton. The great inconvenience however of the Saxon blue is the extreme difficulty of rendering it a tolerably faſt colour, for when applied in the common way it is ſoon deſtroyed by waſhing, eſpecially with ſoap, ſo that the indigo in the ſtate in which it exiſts in this ſolution appears to have but a very feeble affinity with animal or vegetable fibre, a remarkable contraſt to the habitude of the ſame colouring matter when deoxygenated and diſſolved in alkalies.

The colour of the Saxon blue undergoes no notable change like that of the common indigo vats, the ſtuffs dyed in it coming out blue and not green. The colour takes upon woollen cloth with great rapidity, ſo that it is very difficult to dye it uniform through a whole piece. Some ſcientific dyers have thought that this dye was more permanent when the ſolution was ſaturated with an alkali juſt ſhort of the point at which the indigo begins to ſeparate, for an entire ſaturation of the acid will precipitate the indigo nearly unchanged. Other artiſts have thought alum of uſe in this caſe in fixing the colour. The action of acids upon indigo will be further mentioned under the article *Indigo*.

Pruſſian Blue is ſo beautiful a colouring matter for painting, that many attempts have been made to fix it permanently on cloth of different kinds. Pruſſian blue, or pruſſiat of iron, is naturally a faſt colour, reſiſting the action of light and air for any length of time, but when diſſolved in any of the alkalies, or in lime-water, the blue is immediately deſtroyed, and a pale ſtraw colour ſubſtituted. The ſolution is a triple compound of pruſſic acid, iron, and the alkali or lime uſed. If any acid be added to the above pruſſiat to the full ſaturation of the alkali or lime, the blue colour is reſtored without immediately precipitating the pruſſian blue.

Two methods have been adopted of preparing this colour for dyeing, the one, by mixing it with muriatic acid, in which caſe it is only ſuſpended and not diſſolved; the other, by diſſolving it in alkalies or lime, and ſaturating the ſolution to that point at which the blue colour is reſtored. The pruſſian blue in either caſe has ſufficient affinity with the fibre of cloth to unite with it rapidly and firmly.

Some have uſed an acetite of iron as a kind of mordant to the cloth before the application of the pruſſiated alkaline ſolution. It is neceſſary in all caſes where this ſolution is uſed, that it be neutralized with an acid to diminiſh the ſtrong affinity between the alkali and colouring matter, which without this aſſiſtance the cloth alone could not overcome.

Two capital inconveniences have hitherto been found to attend the uſe of this ſubſtance as a blue dye, the one the extreme difficulty of making it take at all uniformly on a moderate extent of cloth; for an immerſion of a very few minutes is found ſufficient to give the full effect of this colour, and hence the dye is depoſited ſo rapidly as to be conſtantly wavy and uneven. The other defect is that it is readily diſcharged by ſoap, the alkali in the ſoap having the ſame effect on the colour fixed in the fibres of cloth as it has on pruſſian blue in ſubſtance, ſo that after a very few waſhings the colour becomes of a dirty yelloviſh brown. Stuffs dyed with this colour therefore muſt be waſhed with bran, or oatmeal, or in any other way in which no alkaline ſubſtance is employed.

A baſis of other colours is often uſed in dyeing with pruſſian blue.

Very beautiful greens are produced with this colour, and the permanent yellows.

Dr. Bancroft, in his curious experiments on this colouring matter, obſerves, that when cotton is printed with a mixture of adjective colours, and an iron mordant *without alum*, and afterwards dyed with pruſſian-blue ſolution, the reſult is not a mixture of the blue with the adjective colour already applied (for example, green, where the latter is a yellow) but is ſimply that colour which the pruſſian ſolution would produce with the iron mordants without the adjective dye: or in other words the pruſſian blue appears merely to diſplace the firſt applied colour, and unite with the iron mordant. It has however the capital advantage of dyeing much more uniformly than in the common way, ſo that in this inſtance the adjective colour appears to divide and diſtribute the mordant more accurately than could be done without it. On the other hand, where the adjective colour is fixed with an alum mordant, the pruſſian blue cannot diſplace it, and therefore unites with it, forming an intermediate ſhade of colour.

Of Yellow.

Yellow is ſo common a colour for the extractive part of vegetables as to furniſh a conſiderable number of dyes, many of which are only uſed extemporaneouſly by uncivilized nations in different parts of the world, and ſcarcely known beyond thoſe parts. The yellow dyes actually employed in this country are few, and it happens unfortunately that the moſt beautiful are not the moſt permanent. All the known yellows are adjective colours, or ſuch as require a mordant, and on the whole this is a dye eaſily given, but always (when on cotton and linen), liable to be impaired by the action of light and air.

Weld (*Reſeda Luteola* Linn.) is a ſlender plant growing to the height of about three feet, and cultivated for dyeing in this country, as in many other parts of Europe. The plant is cut when ripe, and ſimply ſpread out to dry, after which it is tied up in bundles, and uſed in this ſtate without any other preparation. It requires nearly a boiling heat to enable water to extract the colour of weld with effect, and a coction of three quarters of an hour before the whole of the colour is exhauſted, during which time it is looſely tied in a bag, and kept down in the boiler by a heavy wooden frame. The decoction of weld, when concentrated, is a browniſh yellow, when dilute it is more of a lemon yellow with a ſhade of green. Alkalies deepen the tint towards an orange or brown, but acids make it lighter. Alum gives a yellow precipitate in the decoction of weld, and the clear liquor remains of a beautiful lemon colour. Tartar is conſidered as brightening the colour of weld, and the ſolutions of tin produce this effect in a great degree, giving it at the ſame time a yellowiſh green tint of great delicacy.

Weld is conſidered by moſt dyers as, on the whole, the yellow which unites beauty with durability in the higheſt degree.

Wool and woollen cloth is dyed with weld (according to Hellot) in the following way. The wool is firſt cleanſed in the uſual manner, and then paſſed through a bath of about 4 parts alum and 1 of tartar to every 16 parts of wool. The quantity of tartar is determined by the greater or leſs brightneſs of colour wanted to be given. It is then dyed in the weld bath, for which about 3 or 4 parts of weld (often much leſs) are uſed to 1 part of wool. For economy, the weaker ſhades of colour are dyed in the ſame bath after the ſtronger are finiſhed.

A golden yellow with more or leſs orange is given by a weak madder bath after the welding.

Silk is dyed of a golden yellow generally with weld alone. The ſtuff is firſt boiled in ſoap water, alumed and waſhed, then paſſed twice through a weld bath in which, the ſecond time, ſome alkali is diſſolved which gives a rich golden hue to the natural yellow of the weld. A little annotta ſtill further deepens the colour. The ſolutions of tin alſo apply very well to ſilk, and with weld give a bright clear yellow.

To dye cotton yellow[1] it is firſt cleanſed with wood aſhes and water, rinced, alumed, dried without further rincing, and then paſſed through a yellow bath in which the weld is ſomewhat more than the weight of the cotton. When the colour has ſufficiently taken, the cotton is thrown into a bath of ſulphat of copper and water and kept there for an hour, after which it is boiled with white ſoap-water, and finally waſhed and dried.

If a deeper jonquil-yellow is wanted, the aluming is omitted, and inſtead, a little verdigris is added to the weld bath, and the cotton finiſhed with ſoda.

It is particularly in giving the lively green lemon yellow that weld is preferred to all other materials. It is however expenſive, conſidering the ſmall proportion of colouring matter to the weight of the plant, and the dye is not extracted readily with leſs than a boiling heat, which in callico-printing is ſometimes a great inconvenience. It is alſo found to degrade and interfere with madder colours more than other yellows, which is another diſadvantage in printing, where patterns are firſt impreſſed with madder-colours, and the whole finiſhed with a weld bath.

Quercitron Bark. The bark of the American oak (the *Quercus Nigra*, Linn.) long uſed as a yellow dye in the countries where it is indigenous, was firſt introduced into this country by Dr. Bancroft, from whoſe full and elaborate account of its properties the following general facts are extracted.

The colouring matter of this bark may be readily extracted by water only blood-warm. The infuſion in hot water is rather turbid, and there ſeparates by filtration a ſmall quantity of yellow reſin. The infuſion will yield by evaporation an extract which contains the colour in a very concentrated ſtate, but when kept for a ſhort time does not anſwer for dyeing ſo well as the unprepared bark. The decoction of

[1] Berthollet.

quercitron is of a yellowiſh brown, darkened by alkalies, and rendered lighter by acids: alum cauſes a very ſmall precipitate of a deep yellow: the ſolutions of tin produce a very lively yellow and a copious ſediment.

The quantity of colour contained in quercitron bark is very great compared to its weight, much more than in an equal weight of weld, to which it approaches the neareſt in beauty and durability combined.

Wool may be dyed of a faſt yellow with quercitron by being firſt cleaned in the uſual manner, boiled for about an hour with one-ſixth of its weight of alum, in ſufficient water, then without rincing transferred into a copper containing a decoction of as much quercitron bark as there was uſed of alum, and turned through the boiling liquor over the winch as uſual, till the colour appears to have taken ſufficiently.

After this, ſome chalk in the proportion of about one pound for every 100 lb. of the cloth is to be mixed with the dyeing liquor, and the operation continued ten minutes longer, when the proceſs will be finiſhed.

It may be obſerved that chalk or alkali is of great ſervice in all yellow-dyeing, whether with weld, quercitron, or any other colour, when the mordant is alum, as this addition helps to bring out and heighten the dye.

The yellow of quercitron given in this way is however inferior to that of weld.

The ſalts of tin, being powerful mordants for almoſt every colouring matter, may be employed with advantage in dyeing yellow, particularly the fineſt colours. Dr. Bancroft recommends the murio-ſulphat of tin (made by diſſolving 14 ounces of tin in a mixture of two pounds of ſtrong ſulphuric acid, and three pounds of the muriatic) of which 10 lb. with as much quercitron bark, are ſufficient to give the higheſt orange yellow to 100 lb. of cloth. The bark is firſt put into the boiler (tied up in a bag) and boiled with water for a few minutes, after which the tin ſolution is added, the mixture well ſtirred, and the cloth, previouſly ſcoured and wetted, is then paſſed briſkly through the liquor over a winch for a ſufficient time, which is generally no more than a quarter of an hour.

With an addition of alum a pure golden yellow with leſs of the orange is produced; for the delicate green yellows Dr. B. uſes the tin ſolution with both tartar and alum.

The method of dyeing cotton yellow with weld has been already mentioned. A ſimilar way will anſwer with all the yellow dyes, but owing to the ſmall affinity which the fibres of cotton have for colouring matter, it is extremely difficult by any means to fix a full, equal and laſting yellow on this material. Even the ſalts of tin which are ſo uſeful as mordants to wool or ſilk, Dr. Bancroft obſerves to have no good effect with cotton, and to be worſe in every reſpect than alum.

On account of the ſuperior beauty and durability of the yellows given to cotton in the proceſs of calico-printing to thoſe of common dyeing, Dr. Bancroft propoſes the uſe of the printers mordant, the acetite of alumine, in general dyeing. When uſed for this purpoſe it is not to be thickened with gum or ſtarch, but prepared ſimply by mixing one part of ſugar of lead with three of alum and ſufficient water. The cotton (and the ſame applies to linen) ſhould be firſt ſoaked for two hours in the aluminous liquor kept blood-warm and then dried in a ſtove: then ſoaked a ſecond time in the mordant, dried without rincing in water, then ſoaked in lime-water, which tends to fix the alumine in the cloth and neutralizes the acetous acid. After this (or where a very durable yellow is wanted, with a third aluming and liming) it is fit for the yellow bath, in which 12 or 18 pounds are ſufficient for 100 of the linen or cotton. A finiſh with a very weak ſolution of ſulphat of copper ſeems to raiſe the colour.

Some of the further uſes propoſed to be made of the quercitron by Dr. Bancroft, will be mentioned when deſcribing the cochineal ſcarlet and calico-printing.

Old Fuſtic, ſo called in this country, (the *Bois Jaune* of the French,) is the wood of a large tree, the *Morus tinctoria*, which grows abundantly in many parts of the Weſt Indies and the American continent.

Fuſtic is of a ſulphur colour, abounding in colouring matter, which is much more durable than any of the other yellow dyes, inſomuch as when applied even ſubſtantively, or without a mordant, the dye is conſiderably durable, but ſtill more ſo when uſed with the ſame mordants as weld or quercitron.

The decoction of fuſtic in water, when ſtrong, has a deep and ſomewhat dull red yellow, and by dilution becomes orange yellow. Acids produce in it only a ſlight precipitate, which alkalies rediſſolve, rendering the liquor red.

Fuſtic though valuable for the durability of its colour is ſeldom uſed for the pure yellows, as the colour which it gives is dull and muddy. It is chiefly uſed in compound colours, as in

forming green with a Saxon-blue basis; or in producing with a mixed mordant of alum and iron liquor an infinite variety of drab and olive dyes, where the natural dullness of its colour is of no consequence. It is used chiefly in general dyeing and seldom in printing. It goes much further than weld.

Young Fustic, the *Fustet* of the French dyers, *Rhus Cotinus* or *Venice Sumach*, is a shrub growing in Italy and the South of France, which gives a fine greenish yellow but without any permanence, so that it is never used alone, but only as an accessary colour to heighten cochineal and other dyes and give them an approach to yellow.

The common *Sumach* of Spain, Portugal, and other parts of Europe, gives a yellow dye with the aluminous mordant, but very pale and dull. It is therefore never employed for this purpose, but on account of the large quantity of gallic acid it contains, it is of great service in black dyes and all the degradations of this dye.

Saw-Wort (Sarrette, Fr.) the *Serratula Tinctoria* of Linnæus, is a useful plant which gives a good lemon yellow to wool when used with the aluminous mordant.

Dyer's Broom (*Genestrole*, Fr.) the *Genista Tinctoria* of Linnæus, a plant abundant in dry hilly countries, gives a tolerable yellow, which with an alum and tartar mordant is sometimes used in the inferior woollen goods.

Avignon or *French berry (Graine d'Avignon)* is a very beautiful but remarkably fugitive yellow, which can never be used with advantage to the consumer except where a very temporary but fine colour is wanted.

The American Golden Rod (*Solidago Canadensis*) though not commonly introduced, appears by the experiments of able dyers to be one of the very best of the vegetable yellows, little if at all inferior to weld.

Several other vegetables have also been occasionally used for yellow dyes, but are of little importance. In fact scarcely any other substance is actually employed for this colour than weld, fustic, and quercitron.

Of Madder Reds.

The root of madder *(Rubia Tinctorum)* is one of the most important of the colouring matters, on account of the great body and quantity of colour which it possesses, its durability when fixed by proper mordants, and the immense variety of shades of colour which are obtained from it by various admixtures.

Some facts concerning the cultivation and analysis of madder will be described under that article, the general result of the analysis is that madder naturally contains two distinct colouring matters, one of which is of a deep blood-red (for which alone it is valued) and the other of a dun or yellow brown, more soluble than the former, but so intimately combined with it as materially to deteriorate the natural beauty of the red portion.

The natural colour of madder therefore is a dull orange red, with much body but little brightness; but by various means (some of them extremely complicated) the art of man has been enabled to extract and fix dyes of great beauty from this ingredient.

Madder is an adjective colour, its stains being removed from all kinds of cloth without much difficulty by washing and exposure, unless fixed by mordants. Of these the aluminous salts are the most powerful, and most commonly employed. The salts of tin are not used in fixing the colour, but when fixed, they render it more lively.

Wool or woollen cloth when to be dyed with madder, is first soaked in a bath of alum and tartar in varying proportions, but when the latter is in excess the colour, though solid, degenerates to a cinnamon brown. The madder added to the bath of alum and tartar must scarcely be heated more than blood-warm, otherwise the dye will become browner and deeper. At any time however the madder reds on wool are not so beautiful as those on linen or cotton, though easier given, and with more body.

The fixing a permanent, full, and beautiful madder red upon cotton, and especially linen, is perhaps the most difficult and complicated process in dyeing, and one on which more has been written, and more experiments and enquiries have been made than perhaps any other part of this chemical manufacture. The affinity of cotton, (and the same applies to linen) to madder-colour is so small, that even the aluminous mordant will not alone be sufficient to enable it to resist frequent washing, and especially the bleaching effect of the sun's rays. Hence it is found necessary previously to fix into the fibres of the cotton one or more substances capable of uniting with both the mordant and the colouring matter, and to retain them with great force.

There are two principal kinds of madder colours known, but with a great variety of intermediate shades; one is the common red, not very brilliant, but considerably permanent, in which the substances used are chiefly, first, any vegetable substance containing a

large quantity of tan, and above all, galls, ſecondly, an aluminous mordant added to the galled cotton, generally with a certain portion of tartar; thirdly, the madder colouring matter, and fourthly, a finiſh with an alkaline bath, which indeed is not eſſential to the fixity of the colour, but is found moſt materially to heighten and improve it, chiefly as has been ſuppoſed by removing the brown-yellow part of the madder which always mixes more or leſs with the red, and degrades it. The other madder colour is a very bright, beautiful, and moſt durable red, which, from having long been, and being ſtill prepared at Adrianople, and other parts of the Levant, with a perfection ſcarcely imitable, is called the *Adrianople or Turkey Red*, and if the accounts of its preparation are accurate, it is the moſt complicated and tedious proceſs in the whole art of dyeing.

The true Adrianople red, beſides its uncommon beauty, has the property of reſiſting more than any other madder red, the action of ſoap, alkalies, alum, acids, and all other reagents. On this account nitric acid is employed as a teſt to diſtinguiſh this red from any ſpurious imitations. If the latter is immerſed in aqua-fortis, or common nitric acid, it ſoon loſes colour, and in about a quarter of an hour it is quite white, whereas the genuine Turkey red cotton will remain nearly an hour without any perceptible loſs of colour, and retains an orange tint to the laſt.

There can be no doubt too that much of the beauty of the Levantine red is owing to the ſuperior quality of the madder, as will be noticed under that article, ſo that even with the beſt madder of the North of Europe, it is probable that no accuracy in the dyeing can entirely make up for this radical difference.

We ſhall not detail the *ſeventeen* diſtinct operations (given by the Abbé Mazeas) as employed in this proceſs, but only deſcribe the general way of proceeding.

The cotton yarn is firſt thoroughly cleanſed by long boiling in water. The next ſtep is to impregnate it with an *animal* ſubſtance, which, having a much ſtronger affinity for colouring matter than the cotton itſelf, forms an excellent baſis or ſubſtratum on which the dye may fix itſelf by the ſubſequent operations. The animal matter in this inſtance is ſheep's dung. Oil is another intermede alſo uſed, and the effect of this is certainly to aſſiſt in fixing the colour, and rendering it afterwards inſoluble in all other ſubſtances. The oil and the dung are blended, and both together diſſolved in a ley of ſoda, and the cotton well mixed with it with much manual exertion.

The cotton is then ſteeped in olive oil, without the dung, brought to the ſtate of a milky liquid, or an extemporaneous ſoap, by juſt ſufficient ſoda. It is then ſteeped in three ſucceſſive baths of ſoda and water, each ſtronger than the laſt, in order thoroughly to ſeparate all the oil that looſely adheres to the cotton, or all but what is intimately combined with it. This is neceſſary to make it take up the ſoluble part of the galls with which it is combined in the next operation. A ſtrong decoction of galls is then made, and the cotton is long and thoroughly ſteeped in it, with much wringing and preſſing, after which it is ſtretched and dried as quickly as poſſible.

The cotton now may be conſidered as a compound of vegetable fibre with the animal matter of dung, with oil, and with tan very intimately combined, and it is then in the ſtate fit to receive the proper mordant for the madder colour. This mordant is Roman alum, in which the cotton is carefully ſteeped for a due time, and then ſtretched and dried.

After this long preparation the cotton undergoes an exact repetition of the whole proceſs ſtep by ſtep, the dung bath only excepted; that is, of oiling, ſteeping in ſoda, galling and aluming.

The whole of this labour being performed, the cotton is thoroughly dried and aired, and is then of a dun or root colour, this hue being given by the galls. The next ſtep is the maddering, but in order more fully to animalize the cotton a ſmall quantity of ſheep's blood is mixed with the water in the boiler in which the madder is diſſolved. The ſelection of the madder depends on the preciſe colour required to be given; the quantity is always twice the weight of the cotton. When this bath has got to a lukewarm heat the hanks of cotton are ſteeped in it well ſtretched on wooden frames that keep the thread ſufficiently aſunder to allow the dye to penetrate thoroughly and uniformly.

This ſteep laſts an hour, during which the heat of the bath is ſlowly increaſing, and after it begins to boil, the cotton is taken off the frame and let to lie looſe in the veſſel for an hour longer, the liquor being all the while kept at a boiling heat. After this, the colour of the bath being exhauſted, the cotton is taken out and waſhed in running water, ſtretched, and dried. Laſtly the cotton, now thoroughly and durably dyed, is finiſhed by being boiled for four or five hours in a cloſely covered veſſel in a ſolution of white Marſeilles ſoap, olive oil, and

ſoda. This finiſhing brings out the colour, and much increaſes its richneſs and durability.

Such is, according to the beſt authorities, the curious and complicated proceſs for dyeing the beautiful Adrianople red. On the whole it appears that the ſaving which may be made in imitating this proceſs is rather in the number and extent of the different operations, than in the actual omiſſion of any one part. The animal matter, the oil, the ſoda, the galls, and the alum, appear all to have their diſtinct uſes, and probably it would be very difficult to diſpenſe with any of them (or ſubſtances ſimilar to them) without injuring the perfection of the dye.

The fine imitation of this colour made at Montpellier is conducted in a manner cloſely following the Turkey proceſs according to the teſtimony and actual experience of Chaptal.

The obſervations of this excellent practical chemiſt give many important rules with regard to the choice and uſe of the materials too minute to be fully detailed in this place. Inſtead of ſheep's dung the gaſtric liquor contained in the ſtomach of ruminating animals is employed, in each caſe, mixed with the oil and ſoda into a kind of oleo-animal ſoap. The oil ſhould be of that kind which remains permanently united with cauſtic alkali into a uniform milky ſoap, without ſubſiding or running again into drops in any ſenſible degree. This kind of oil is probably that which is the freeſt from extractive matter, and the obſervations of other chemiſts have found that linſeed oil which contains very little extract is even better than any kind of olive oil.

It alſo ſeems neceſſary that in the mixture of oil and alkali the oil ſhould be in exceſs, or in greater quantity than in the proportions which conſtitute common ſoap: for the uſe of the alkali is chiefly to divide the oil and enable it to penetrate uniformly into the cotton, but if there were no exceſs of oil it is not likely that the alkali would abandon any of it to the fibres of the cotton. Soda does not appear to be eſſential, potaſh being found to anſwer as well.

The galling is one of the niceſt operations. The cotton ſhould be made to take the galls very uniformly, and ſhould be dried rapidly, as the action of the air is found ſo far to affect the ſoluble matter of the galls that, if much expoſed to it, the outer part of the cotton will become dark, and the remainder grey, and the ſubſequent colour will in conſequence take unequally. Sumach is uſed with the galls in rather a larger proportion. The repetition of the oiling, galling, and aluming is practiſed at Montpellier as in Turkey. In the finiſhing part two operations are uſed. The firſt is, as in Turkey, boiling with ſoda and ſoap in a very high temperature. The boiler is cloſely fitted with a ſtrong cover with only a very ſmall hole for the exit of the vapour, and by the heat of the fire beneath the confined liquor is made to receive a heat certainly above that of common boiling, ſimilar to what takes place in a digeſter. This brings out the colour to a very beautiful red, but it is further heightened by the final operation which was long kept ſecret, and which conſiſts in paſſing the cotton through a mixed ſolution of nitro-muriat of tin and alum, at a blood heat.

Linen thread is dyed of a fine red by the ſame method, but a ſtill greater number of ſucceſſive operations are required, and in particular the alkaline leys ſhould be much ſtronger.

Madder reds of extreme beauty are prepared by the Armenian dyers ſettled at Aſtracan. The proceſs as given by Profeſſor Pallas[m] is more ſimple than that practiſed at Adrianople, but agrees with it in the eſſential particulars. The madder is a fine ſort that grows wild in ſeveral parts of Perſia, and is dried and ground for uſe. The oil employed is procured from the entrails and refuſe parts of the ſturgeon, beluga, and other fiſh that are ſo abundant in the Volga. This ſupplies both oily and animal matter. The alkali employed is a coarſe native ſoda, prepared by burning various ſalt plants in the vicinity. But the oil ſeems to be uſed without alkali, the ſoda being only employed in the finiſhing. The general proceſs is as follows: the cotton yarn previouſly waſhed and well dried is laid in a tub, and covered with the fiſh oil, where it remains for the night. In the morning it is taken out and hung up in the air on poles. This alternate ſteeping in oil during the night and airing during the day is continued for a week, after which the yarn is waſhed in the river and dried. A ſtrong decoction is then made of pulverized ſumach leaves and galls, to which, when ſtill hot, alum is added. The galls and alum are in the proportion of 5 pound of each to every pud (40 lb.) of cotton. This compound liquor is poured on the cotton, and well worked in with the hands, and the yarn again dried. It is then fit for the maddering, in which ſheeps blood is here alſo uſed along with the madder. The whole operation is finiſhed by boiling the dyed

[m] Tooke's Ruſſian Empire vol. iii. p. 497.

cotton with a ley of impure soda in large clay pans with a very narrow neck, and set in brick over a fire place. The boiling continues for twenty-four hours.

A dye-house for giving to cotton yarn a fine red equal to the Turkey red was established at Glasgow by Mr. Papillon, the secret of which was purchased by the Commissioners for Manufactures in Scotland, and has been made public not long since.[a] It consists of a very close imitation of the Adrianople process, as already described, but with a considerable saving in the length and number of applications. The particulars need not be here enumerated, but it may be mentioned generally that it consists of the distinct operations of boiling with soda, —steeping in a compound bath of sheep's dung, oil, soda and other ingredients—oiling without the dung—galling—aluming—dyeing with madder and blood—fixing the colour with the dung and oil steeps—and lastly brightening the dye with a finish of soap-water and soda.

Mr. Haussman in his observations upon Adrianople processes, announces a great simplification in the number of processes and an alteration in the mordants, by which he asserts that a red may be procured fully equal to that of the Levant.[b] The mordant which he proposes is a compound solution of alumine and oil in caustic alkali, and is made in the readiest way by adding caustic alkali to a hot concentrated solution of alum, which first precipitates, then redissolves the alumine, after which a small portion of linseed oil (and probably fish oil would answer full as well if not better) is to be put in, and the whole mixed into a cream-like liquor. Cotton steeped twice (or where fine colours are wanted, thrice) in this alumino-oily soap appears to be then fit for maddering and to retain the colour in great perfection.

To give a full dead-red like that of the India handkerchiefs, Berthollet directs that the cotton should first be boiled in lime-water; then steeped in the bath of soda, oil, and gastric liquor of sheep or other ruminating animals; washed; steeped in a mordant of acetite of alumine (made by alum and sugar of lead) and lastly maddered. In this case the finishing process is not required. The colour thus produced is a full red without lustre, and the deadness of colour appears to be owing to the lime-water.

Cotton dyed red may be brought down through all the intermediate shades to a pale orange, by steeping for a longer or shorter time in nitrat of tin. As a general rule, to give the brighter colours the cotton must be but moderately oiled and galled, steeped for a length of time and often in alkaline leys of the weaker sort, largely alumed, dyed with the best and brightest madder, and at the last long and plentifully soaped.

Such in a general way are the processes by which the red colour of madder may be made durable on cotton and linen. The shades of degraded red producible by adding any iron solution to the aluminous mordant are endless. It may only be added that for the sake of economy the same bath may often be used with advantage, both for the fine bright reds and for the violets, wine colour, and other darker shades, by employing for the former the madder bath when first warm and fresh, and for the latter the same bath when fully boiled, where the dun yellow part of the madder begins to prevail, and in which it can produce no material injury to the intended colour.

Of Cochineal Scarlet and Red.

Whoever casts his eyes on a piece of broadcloth dyed in the most perfect manner with the fine or cochineal scarlet, must be struck with its transcendant beauty and lustre, and acknowledge it to be one of the finest efforts of the art of dyeing.

The scarlet dyeing in general makes a distinct branch of trade, the materials being of that delicate kind as easily to be hurt by accidental admixture of other colours, and part of the apparatus being somewhat different from that of common dyeing. The boiler in which the cochineal bath is made is generally of tin or strongly tinned copper, for as a solution of tin is the mordant employed, no harm can arise from its being in contact with the same metal, but copper might be somewhat acted on in the process and the dye injured. The quality of the water is also of importance here, which should be soft and pure, for hard water tends to produce a rose colour, which however is corrected by boiling bran or starch in it.

Cochineal (the peculiar nature of which is described under that article) contains a vast quantity of colouring matter in proportion to its weight, and yields it very readily to water cold or hot. The infusion of cochineal is naturally of a fine crimson, and is entirely an adjective colour, but with a mordant it fixes on woollen and silk with great firmness, but weakly and with difficulty on linen and cotton.

Alum appears to have been the mordant first employed to fix the colour of cochineal on wool.

[a] Phil. Mag. vol. 18.

[b] An. Chim. tom. 41.

It does not ſenſibly alter the natural tint, as it gives a deep and durable crimſon. It even reſtores the crimſon to cloth dyed ſcarlet by the compound tin mordant.

The aſtoniſhing effect of all the ſolutions of tin in heightening the colour of cochineal, appears to have been firſt diſcovered and put in practice by one Kuſter, a German, who ſettled at Bow, near London, about the year 1543,[a] whence ſcarlet was called the Bow dye in this country. It has been generally ſuppoſed that the change of the natural *crimſon* of this drug to *ſcarlet* was owing ſimply to the effect of the nitro-muriat of tin, which is the common ſolution uſed by the dyers, but Dr. Bancroft has fully proved (as indeed is acknowledged by Berthollet in his ſecond edition) that this is a miſtake, and that the nitrat or muriat or nitro-muriat of tin uſed alone only heightens the colour of cochineal, but does not materially change its natural crimſon; but that it is the addition of *tartar* to the tin ſolution which converts the crimſon to that fiery bright ſcarlet for which this dye is ſo preeminently valuable. Now as ſcarlet is a colour compoſed of crimſon and yellow, and as tartar changes the cochineal crimſon to yellow, it may be inferred that the ſimple effect of the tartrite of tin (which ſalt is formed by double decompoſition when the nitro-muriat of tin and tartar are mixed) is that of adding a yellow. This poſition Dr. Bancroft found by experiment to be accurate; for when cloth was dyed with cochineal, and the tartrite of tin ſingly made by diſſolving this metal in the tartareous acid, the dye was a full ſcarlet. An equal effect was produced by ſubſtituting lemon juice or elſe the pure citric acid to the tartareous. Berthollet alſo found that on dyeing three ſamples of cloth, the firſt with nitro-muriat of tin, tartar and cochineal in the proportions commonly uſed; the ſecond with the ſame ingredients but with a double proportion of tartar; and the third omitting the tartar, that the firſt ſample was of a full ſcarlet, the ſecond a ſcarlet more inclining to yellow, and the third a crimſon.

The ſolution of tin uſually employed by the dyers is prepared in the following way. Dilute nitric acid of the kind called *ſingle aquafortis* is the acid uſed, and may be made by proper management to take up about one-eighth of its weight of tin. A ſmall quantity of tin (previouſly granulated by being poured when melted into cold water, kept briſkly agitated with a bundle of rods) is put into a glaſs veſſel, to which is added the aquafortis mixed with from $\frac{1}{16}$ to $\frac{1}{4}$ of its weight of common ſalt or ſal ammoniac, and ſtill further diluted with water. A ſtrong action begins almoſt immediately, without artificial heat, and it is the buſineſs of the preparer to keep this action as moderate as poſſible, by ſetting the veſſel in a cool place and adding only ſmall quantities of tin at a time, in proportion as the laſt added quantity is diſſolved. By this method the acid becomes fully ſaturated with oxyd of tin, whereas if the heat generated in the proceſs is not checked, or if the acid is too ſtrong, the greater part of the tin will remain undiſſolved in the form of a white oxyd. Even when well made, the ſolution (or *ſpirit* as the dyers call it) is apt to coagulate by mere keeping and to depoſit the oxyd of tin, which it cannot again be made to take up. The uſe of the muriat of ſoda or ammonia is to prevent the ſpontaneous ſeparation of the tin. The muriatic acid ſingly is a much better ſolvent for tin, taking up a large quantity and retaining it for any length of time, but the ſimple muriat of tin, and indeed of many other metals, is found to have a very corroſive effect on the fibres of wool, and even (in a leſs degree) on thoſe of linen and cotton.

To preſerve the muriatic acid in the ſolution, and at the ſame time to combine it with ſome other acid which has not ſuch a corroſive effect on cloth, Dr. Bancroft recommends the murio-ſulphuric ſolution of tin, as equal in efficacy to the nitro-muriatic and much cheaper. For this purpoſe 14 ounces of granulated tin are to be added to a mixture of two pounds of ſulphuric acid of ordinary ſtrength, with three pounds of muriatic acid. No particular precautions are required in making the ſolution, which will be equally permanent with or without artificial heat.

As the ſtate of oxygenation of all metallic ſolutions, and particularly of thoſe of tin, very materially affects all their chemical properties, a few obſervations on this ſubject may be mentioned after deſcribing the proceſs of ſcarlet dyeing.

Woollen cloth is generally dyed ſcarlet in two operations, though a ſingle one will ſuffice, but in general is leſs convenient. To dye a hundred pounds of wool, 8 or 10 pounds of tartar are firſt put into the boiler with a ſufficient quantity of ſoft water, and 6 or 8 ounces of cochineal. Immediately afterwards 10 or 12 pounds of the nitro-muriat of tin are added, and when the mixture is ready to boil, the cloth

[a] Bancroft.

(previouſly wetted) is put into the dyeing liquor and turned through it by a winch for an hour and a half, the liquor being kept boiling the whole time. The cloth is then taken out and rinced, and is found to have acquired by this firſt operation a full fleſh colour. The boiler is emptied, and again filled with freſh water, and when nearly boiling, from five to ſix pounds of powdered cochineal (according to the depth of colour wanted) are thrown in and well ſtirred, after which about 10 pounds more of the ſolution of tin are added, and the cloth is then put in and turned through the boiling liquor at firſt briſkly, afterwards ſlowly, for half an hour. It is then waſhed and dried in the uſual manner. The average proportion of cochineal to dye a full ſcarlet is an ounce to a pound of the cloth, and hence from the high price of this article the cochineal dye is one of the moſt (if not the moſt) expenſive of all the proceſſes in the whole art of dyeing.

This dye may be given apparently with equal effect by a ſingle proceſs, that is, by mixing together the whole quantity of tartar, ſolution of tin, and cochineal at once, and paſſing the cloth through the bath for a ſufficient time; for the affinity between the wool, and the mordant, and the colouring matter is ſo ſtrong, that this triple union takes place at once, and with great force. Or the whole of the tin and tartar may be uſed in the firſt operation, and the whole of the cochineal in the ſecond.

It may alſo be obſerved that a great difference is found in the reſpective proportions of theſe ingredients, uſed by different dyers.

When a very bright flame-coloured ſcarlet is wanted, a little yellow fuſtic is added to the firſt bath, or elſe ſome turmeric is added to the cochineal in the ſecond. This gives both a yellow ground and mixes a portion of yellow with the ſcarlet. Theſe additions are diſcovered by cutting the cloth, for in this caſe the inner part will be found dyed ſimply yellow, the reaſon of which is, that in the common proceſs the cochineal does not penetrate the inner part of the cloth, ſo that where theſe yellows are not uſed, this part remains white. If the ſcarlet has too much of an orange tint, this is corrected by afterwards boiling the cloth in hard water, or one that contains any earthy ſalt.

It is on account of the caſe with which almoſt any alkaline or earthy ſalt counteracts the yellow part of all theſe colours, that ſcarlet cloth is always changed more or leſs to a roſe or crimſon by the proceſs of fulling. Hence too the ſcarlet is always given to wool after it is manufactured, and not in the ſtate of yarn.

After the full ſcarlet has been given to the cloth, the liquor ſtill retains part of the cochineal with a large portion of the mordant, and this is uſed for the lighter dyes, or with the addition of fuſtic, madder, and other ingredients, it is employed for a vaſt variety of mixed or degraded reds, orange, &c. Much technical ſkill ſeems to be required to make the utmoſt advantage of theſe reſidues, which are ſtill very valuable.

It does not exactly appear in what ſtate of oxygenation the common dyer's ſolution exiſts, but probably before the colour is completely brought out, the metal is oxygenated in the higheſt degree. The nitric acid indeed when uſed alone, if weak and if the ſolution be made very ſlowly, and without heat, is found by Prouſt to contain the *ſub-oxyd* of tin, or this metal in a very low ſtate of oxygenation; for it is only in this ſtate that it remains ſoluble, and when more highly oxygenated it totally ſeparates from the acid in the form of a white perfect oxyd.

But the muriat of tin on the other hand may contain either the perfect oxyd or the ſub-oxyd, the latter is the caſe when the ſolution is recently made, and has not been expoſed to the air, from which it greedily attracts oxygen, but in this caſe without ſeparating from its acid ſolvent.

The muriat of tin, loaded with metal by being boiled on more than it can take up, if cooled to the freezing point gives abundance of cryſtals, which however again liquefy at a ſummer heat, and hence muſt be kept in a cool place. Mr. Hauſſman [q] diſſolved one ounce of this ſalt recently made in 8 pints of water, to which he added with conſtant ſtirring an infuſion of 2 ounces of cochineal in 8 pints of water. A very deep violet coloured precipitate ſubſided, (a mixture of the ſub-oxyd of tin with the colouring matter of the cochineal) which however by expoſure to air gradually turned to a fine carmine: but kept cloſe in a bottle no ſuch change of colour took place. If the ſolution of tin is expoſed to air before mixture with the cochineal, the precipitate becomes carmine much more ſpeedily, as it already contains nearly oxygen ſufficient for this purpoſe. The carmine-coloured oxyd turns ſomewhat crimſon by the addition of ammonia, but returns to carmine when this alkali is again evaporated.

If a carbonated alkali is added to the muri-

[q] Jour. de Phyſ. tom. 48.

ated *ſub-oxyd* of tin, a carbonated ſub-oxyd is ſeparated, which is very greedy of oxygen, but if added immediately to dilute nitrous, or dilute ſulphuric, or acetic acid, diſſolves therein with eaſe and produces a nitrated, ſulphated, or acetited ſub-oxyd of tin. The nitrated ſub-oxyd however ſhews different properties from the common dyers ſolution, producing only a violet or dull crimſon with cochineal, which afterwards heightens in colour by expoſure to air.

An acetited ſub-oxyd of tin is alſo formed, as Mr. Hauſſman has alſo obſerved, by adding equal parts of cryſtallized muriat of tin and acetited lead with ſufficient water, and decanting the clear liquor from the muriat of lead formed by double affinity. This liquor to retain its ſtate of ſub-oxygenation ſhould be kept in a cloſe-ſtopped veſſel, and when mixed with cochineal gives alſo a deep violet precipitate, which requires an expoſure of ſome weeks before it entirely changes to red or carmine.

Mr. Hauſſman propoſes the acetite of tin as a mordant in topical dyeing, either to calico or any other ſubſtance, and with any ſuitable dyeing drug. As the acetites are much better mordants for printing than the ſalts with the three mineral acids, the acetite of tin may perhaps be of uſe in this ſpecies of dyeing, but when prepared with acetited lead there is always a danger of ſome lead being mixed with the ſolution of tin, which may materially and unexpectedly alter and degrade the colours.

Crimſon is given to cloth in two ways, either directly, or by changing the ſcarlet dyed in the manner already deſcribed. All earthy ſalts and eſpecially alum, will change the cochineal ſcarlet into crimſon, when boiled with it for an hour or more. Very hard water will produce the ſame effect without any addition. Hellot found that muriat of ammonia with a little potaſh gives almoſt immediately a beautiful roſe colour to ſcarlet.

To dye cloth directly of a full crimſon the ſame materials are uſed as for ſcarlet, but leſs of the tin ſolution is employed, and alum is added to the bath. They are ſometimes finiſhed with litmus and potaſh, which add much to the luſtre and depth of colour, but this finiſh is only ſuperficial and extremely fugitive.

Silk is dyed crimſon in the following way. It is firſt prepared by boiling with ſoap as uſual, but not ſo compleatly, as it is rather of ſervice to leave a ſhade of the natural yellow, which it is the object of the ſoaping to deſtroy. It is then alumed very ſtrongly and for a conſiderable time. The dyeing bath is made with the uſual materials for ſcarlet, that is, ſolution of tin, tartar, and cochineal, but it is alſo found expedient firſt to add ſome galls to give a baſis to the ſilk to receive the cochineal dye. The particular management in the cochineal bath need not be deſcribed.

The crimſon is often ſlightly browned by paſſing the dyed ſilk through a weak bath of ſulphat of iron. If an approach to flame colour is wanted, the ſilk is finiſhed with fuſtic.

It is impoſſible to dye ſilk ſcarlet by the ſame method as that employed for woollen cloth, for inſtead of this fine colour, the ſilk treated in this way would loſe its luſtre and only take a very faint dye. It appears ſtill to be a point hardly attained, though very deſirable, to give to ſilk a full durable ſcarlet equal to that on woollen.

Cochineal is very ſeldom uſed to cotton or linen, as no method is yet known (except as a lucrative ſecret to one or two individuals) of giving a good cochineal ſcarlet to theſe ſubſtances; and in general the effect of this dye on linen and cotton is not ſo much ſuperior to the cheaper madder and other colours as to be at all adequate to the coſt of cochineal.

Of Reds from Kermes, Coccus Polonicus, and Gum-Lac.

Theſe three ſubſtances all give different ſhades of red, of at leaſt as much durability as thoſe of cochineal, but much leſs brilliance, and they are ſo totally diſuſed in this country, and nearly ſo in other parts of Europe, that a very ſhort notice will ſuffice.

The Kermes (Coccus Ilicis) is a ſmall inſect found in many parts of Aſia and ſouthern Europe. *(See the article Kermes.)*

It gives a high red both to water and alcohol.

Wool intended to be dyed with it is firſt boiled in bran water, then alumed with alum and tartar, to which ſour ſtarch liquor is often added. In the dyeing proceſs nearly equal parts of kermes with the cloth are required, whereas cochineal need not be more than about $\frac{1}{16}$ of the wool. The dyed cloth may be finiſhed with ſoap water, which gives a crimſon caſt.

The dye of kermes is ſo durable that tapeſtry 200 years old was obſerved by Hellot[r] to have loſt nothing of its depth of colour, during ſo long an expoſure to ſun and air. The kermes ſcarlet was anciently called in France *Ecarlate de Graine* (or ſometimes *Venice Scarlet.*) It may be prepared in the ſame way, generally, as the cochineal ſcarlet.

The kermes red is much leſs lively than that

[r] Mem. de l'Acad.

of cochineal, and tends more to the colour of blood. It has the great advantage however of reſiſting ſoap and other ſubſtances very well, ſo that greaſe ſpots may be got out of kermes-dyed cloth without any detriment. On the whole it ſeems very worthy to be retained. Silk has never yet been made to take more from it than a ruſty red.

The Coccus Polonicus is a ſmall round inſect, found adhering to the roots of a ſpecies of the polygonum. It is not known to be employed in the dye-houſes in Europe, but is uſed in Poland and countries where it is indigenous, and alſo in Turkey.

Lac or *Gum Lac* (which ſee) is a gummy-reſinous ſubſtance ſomewhat reſembling bees-wax, occaſionally uſed in dyeing, though rarely, if ever, in this country. A part only of the colouring matter is ſoluble in water, and it gives a dull red but very durable dye, which has been uſed with advantage mixed with cochineal.

Of Reds and Violets from other ſubſtances.

Many of the lichens are capable of giving different ſhades of purple, red, violet and the like, and theſe colours are ſo far ſubſtantive that no mordant will ſenſibly encreaſe their durability, but they are all more or leſs fugitive, and can only be uſed with propriety to give a gloſs or finiſh to articles already dyed. The ſubſtance called *turnſole*, *archil*, or *litmus*, is the beſt known of all the lichens, and is uſed pretty largely eſpecially in ſilk-dyeing. (See the articles *Lichen* and *Litmus*.)

Carthamus or SAFFLOWER is another beautiful and delicate red, verging towards orange, ſometimes uſed in dying, but is fugitive. It is the colouring material of the rouge uſed as a coſmetic.

Brazil Wood or *Fernambouc* is an article of much more importance than any of the preceding, and is employed very largely in dyeing. The natural colour of this wood is a purple-red, and by different mordants it may be made to aſſume moſt of the ſhades of colour connected with red.

The great inconvenience attending the uſe of Brazil wood is its fugitive nature, and no method ſeems yet to be found which will prevent its loſs of colour by conſiderable expoſure to air, and its degradation by ſoap and alkalies. Hence the Brazil wood colours are ſometimes called *falſe* dyes, being much inferior in durability to the *true* dyes given by cochineal or madder. The colour of Brazil wood requires a mordant, which is uſually alum with a ſmall quantity of tartar. This both gives a certain durability to the dye and turns the natural purple to a clear red. Too much tartar gives a yellow tinge. It requires long boiling to exhauſt this wood of its colouring matter. Nitro-muriat of tin is alſo an uſeful mordant, and gives much brilliance to the colour.

Silk is dyed crimſon with this wood, and the colour is nearly as beautiful as the cochineal crimſon, though much leſs durable. The ſilk is firſt prepared with white ſoap, then alumed, and then paſſed through a ſtrong decoction of the wood. When the ſhade is too red it is brought to a crimſon by finiſhing with a weak alkaline bath. When a very deep crimſon is wanted, logwood decoction is mixed with that of the Brazil wood. Silk will not admit of the tin mordant with this wood any more than with cochineal; owing, as appears, to the too rapid precipitation of the colouring particles before they can properly fix themſelves to the fibres of the ſilk.

Cotton takes the Brazil wood colour with difficulty, and this is always liable to be changed by ſoap.

The moſt permanent Brazil wood colours are thoſe in which the natural purple-red is changed to orange or yellow by acids, but it is chiefly for the red, crimſon, and purple hues that this dye would be the moſt valuable, if any means could be found to render them permanent.

Logwood or *Campeachy Wood* is, like the former, a very hard heavy wood of a deep red or orange red colour, and largely employed in dyeing. The chemical properties of logwood will be deſcribed under that article.

The colour of logwood is extracted by boiling with water, and it then forms a deep violet red or purple decoction, like Brazil wood made yellow by acids and deepened by alkalies. The colour of logwood is more violet than Brazil wood, and it alſo contains much more gallic acid, and hence its uſe with iron liquor in all black dyes, as has already been mentioned. The red or purple of logwood is not permanent, but with alum and tartar it gives a fine deep violet, and is often uſed for this purpoſe. A fine blue is alſo given by diſſolving verdigris in the decoction of this wood.

Silk is dyed violet by logwood on an alum mordant.

Of Fawn, Buff, or Nankeen Colour.

Almoſt all vegetables contain in the bark or cortical part a colouring matter of a ſhade approaching either to brown or yellow with more or leſs of red, which has a certain and often a

very ſtrong affinity with the fibres of wool, linen and cotton, and may even frequently be fixed permanently in theſe ſubſtances without any mordant. A great portion of this colouring matter is pure tannin, the colour of which is naturally of a light dun yellow. It is alſo often mixed with gallic acid, and hence theſe ſubſtances may be made to produce an infinite variety of ſhades compoſed of brown-yellow and black in different proportions by the uſe of an iron mordant. Of theſe the commoneſt are walnut huſks and ſumach.

The outer bitter huſk of the *Walnut* is well known to be green at firſt, but by expoſure to air it turns of a deep browniſh-black, ſo as to give the fingers a very durable brown ſtain. The decoction of this ſubſtance ſlowly evaporated forms ſucceſſively a number of pellicles at the ſurface, which when well waſhed are nearly black, and in which nearly the ſame change ſeems to have taken place ſpeedily as occurs by long expoſure in a moderate temperature. Alkalies do not ſenſibly alter the colour of the decoction, but acids brighten it and give a decided yellow caſt. Alum gives a very ſmall fawn-coloured precipitate; ſulphat of iron turns it black, and even oxyd of iron boiled in the decoction is diſſolved therein and forms a dark ink.

The root and bark of the walnut-tree gives a decoction much reſembling the fruit-huſk.

The colouring part of this ſubſtance has a ſtrong affinity to wool, uniting with it nearly as ſtrongly without as with mordants, and giving it a very faſt buff or fawn colour; but alum encreaſes the denſity of the dye and makes it ſomewhat lighter in colour.

Walnut-huſk forms an excellent dye for wool both by itſelf and as a baſis for other colours. The huſks will keep for more than a year in tubs covered with water.

Sumach is a very extenſively uſeful article of dyeing both for all the fawn and buff colours, and with an iron mordant for various ſhades of grey to black. It requires a mordant to fix it on ſtuffs, but then is very durable. With alum it gives a greeniſh yellow, with a mixture of acetite of alumine and iron liquors it gives a grey, and with iron liquor alone, a black.

A good, bright, and durable nankeen colour is given to cotton by iron liquor, the cotton being previouſly prepared with dung and alkali, nearly as in the firſt part of the Turkey red proceſs. This method of nankeen dyeing, as given by Mr. Brewer,[*] conſiſts of eight operations, the firſt, ſecond and third of which are to give the cotton yarn a preparation in a bath of ſheep's dung and ſoap; the fourth a bath of pearlaſh; the fifth is the dyeing with iron liquor; the ſixth a pearl-aſh bath; the ſeventh a ſouring with dilute ſulphuric acid, and the eighth, a finiſh with ſoap. The iron liquor is chiefly the aceto-tartrite, or that which the calico-printers moſtly prepare by diſſolving iron in an acid made of any fermented materials, or of pyroligneous acid, or alder bark and buds, or many other vegetable matters that either contain a naked vegetable acid, or are able to produce one by fermentation. The cotton is firſt ſoaked in this acid iron-liquor, after which it is ſuperſaturated with pearlaſh, ſo that probably a ſolution of oxyd of iron in carbonated alkali is formed, which finiſhes the dye and gives it durability. The uſe of the ſulphuric acid is to diſſolve out all the iron that only looſely adheres to the ſtuff, which being chiefly the red oxyd, the colour becomes clearer and brighter by the loſs.

Of Green.

Though nature abounds with this colour, it is rather ſingular that no vegetable has yet been diſcovered capable of giving to cloth of any kind a green of any tolerable permanence. This dye is therefore always a compound colour formed in dye-vats either by putting a yellow on a blue ground (which is the commoneſt) or a blue on the yellow ground, or by firſt mixing the blue and yellow materials and dyeing with theſe as with a ſimple colour.

Much nicety in the practical part of dyeing is ſhewn in the proper raiſing and fixing of this colour, and many proceſſes of particular excellence are carefully confined within the walls of different manufactories. The general methods however are ſimple and well known.

The common and moſt permanent green on woollen cloth is given in the following way. The cloth previouſly dyed blue in the indigo vat (with more or leſs body of colour according to the body of green required) is firſt well ſcoured, then dyed in a bath of weld or any other yellow dye with alum and tartar, almoſt exactly in the way followed for the ſimple yellows, but with a greater quantity of the yellow materials than would be required for the yellow alone of equal body. Very deep greens have ſometimes a ſlight brown or kind of burniſh given to them by adding to the bath ſmall quantities of logwood and ſulphat of iron. For ſilk the proceſs is reverſed, being firſt ſtrongly

[*] Dublin Society Tranſactions, vol. 1. or Phil. Mag. vol. 17.

alumed, then dyed yellow with weld, and afterwards finiſhed in the indigo vat. It is much more difficult to fix the colour evenly on ſilk than on wool, for the ſilk when ſtrongly alumed takes the dye ſo rapidly that it is apt, without great care, to become wavy or ſpotted.

Another kind of green dye, more bright and beautiful than the laſt but not quite ſo permanent, is the *Saxon Green*, ſo called from the blue part being given by the Saxon blue or ſulphat of indigo. This colour may be dyed by firſt giving a ground of Saxon blue, then aluming, and then paſſing the cloth through a yellow bath. Fuſtic is commonly preferred as the yellow material, as being leſs altered by the adhering acid of the ſulphat of indigo than weld or the other yellows. To correct this effect of the acid and enable quercitron to equal the fuſtic in this reſpect (whilſt its natural colour much excels it) Dr. Bancroft adviſes after the cloth has received the blue to mix chalk with the alum mordant to neutralize the adhering acid, before the yellow is given.

The Saxon green may alſo be given in a ſingle bath: for which purpoſe the cloth is firſt alumed and well rinced; then a ſtrong decoction of fuſtic is made, to which when cooled to a blood heat is added the ſulphat of indigo, and the cloth dyed therein with the uſual precautions. Beautiful Saxon greens may be dyed in a ſtill more expeditious way, according to Dr. Bancroft, by uſing the compound alum and tin mordant. The proceſs he adviſes is the following. Put into the boiler 6 or 8 lbs. of quercitron bark to every 100 lbs. of cloth, boil with ſufficient water, then add 6 lbs. of the *muriſulphat* of tin (in preference to the nitro-muriat) and 4 lb. of alum: when theſe have boiled five or ſix minutes, lower the heat with cold water to blood warm, after which add as much ſulphat of indigo as may be thought neceſſary for the intended depth of colour, and then dye the cloth in this bath with proper care.

Silk, cotton, and linen are dyed green in the ſame general way, but with conſiderable variation in the detail of the different proceſſes, and the ſame difficulties that attend the fixing a ſingle colour on theſe ſubſtances apply to the compound colour.

The moſt beautiful green hitherto known, and one that reſiſts the action of light and air perfectly well, is given by the combination of Pruſſian blue and yellow, but like the ſimple blue from this colouring matter it is deſtroyed by ſoap and alkalies. It is given to cotton by firſt dyeing it olive with weld, or any other yellow dye, and a compound mordant of alum and iron, and then raiſing the green by pruſſiat of potaſh in the manner deſcribed under the Pruſſian blue colours. In this proceſs, as Berthollet obſerves, there ſeems to be a mutual diſtribution of the mordants and colours, the Pruſſian colour taking the iron and becoming blue, whilſt the alum and weld remaining in the olive, form a faſt yellow and unite with the blue into a fine green.

The only ſimple green commonly uſed is that of the carbonated oxyd of copper precipitated from verdigris by an alkali. A ſolution of verdigris is made in vinegar, and a few hours before dyeing a ſolution of as much pearlaſh as verdigris is added to it, the mixture is heated, and the cotton previouſly alumed is paſſed through this bath. The colour thus given is a ſoft apple-green.

Of other Compound Colours.

By the mixture of red and blue in different proportions, violets, purples, lilacs, and vaſt number of other agreeable dyes are formed, but of which it would be tedious to attempt an imperfect detail. In like manner the coquelicots, brick-colours, cheſnuts, cinnamons, &c. are formed from the intermixture of red and yellow. It may be added that in cotton dyeing, advantage has been taken by Chaptal of the difficulty with which cotton ſtrongly alumed and oiled (as for the Turkey red) imbibes watery liquids, to give a ſingular variety of ſhade in the ſame piece, according to the direction in which it is ſeen, and which gives the effect of a number of ſmall irregular ſtreaks over the ſurface. If cotton previouſly oiled, alumed and galled be only ſlightly paſſed through a bath containing ſulphat of iron, the nap of the cloth alone becomes entirely black and the thread grey: if this be afterwards maddered, the thread becomes red and the nap violet, which produces an agreeable changeableneſs of colour as ſeen in different lights.

Of Calico Printing.

To apply a coloured pattern on a white or coloured ground, only two general methods appear practicable, the one, to weave the pattern into the cloth with threads dyed of the requiſite colours, the other to deviſe ſome method of topical dyeing, which ſhall, like a picture, confine the deſired colours to thoſe parts only that are figured by the intended patterns. The former is the delicate buſineſs of the embroiderer or the tapeſtry weaver; the latter is the ingenious art of the calico-printer.

The hiſtory of this art and the detail of the

vaſt variety of proceſſes employed in producing the various coloured patterns, it would be ſuperfluous to enter into, eſpecially as moſt of what has been deſcribed of general dyeing applies (as far as the chemical principles of the art are concerned) to topical dyeing. A few examples therefore of the peculiar manipulations of calico-printing will ſuffice.

It is particularly, though not entirely, with the adjective colours, or thoſe that require a mordant, that calico-printing is concerned, as this very circumſtance affords a ready method of giving a permanent colour only to the pattern part; for if this latter only is impregnated with the mordant, and the whole cloth is then uniformly dyed, the natural effect of expoſure to ſun and air, will be to diſcharge all the colour from every part of the cloth except where it had previouſly received the mordant, and thus a coloured pattern will be produced on a white ground.

This partial application of mordants therefore followed by general dyeing, conſtitutes the greater part of calico-printing, beſides which, however, a further variety of application often occurs, as ſometimes colours themſelves are painted or pencilled in to aſſiſt the general effect, which therefore require no ſubſequent operation; and occaſionally other contrivances are uſed to fix, or alter, or diſcharge colours, according as the propoſed pattern may require it.

Two mordants are more particularly uſed by calico-printers, though equally ſerviceable in general dyeing, the one is acetite of alumine with a portion of alum, the other is a ſolution of iron in ſome vegetable acid.

The acetite of alumine is always made by double decompoſition of alum and ſugar of lead, but the proportions of each vary much according to circumſtances, and probably to the fancy of the colour-mixer. In general three pounds of alum (or in that proportion) are thrown into a barrel, and when diſſolved, a pound to a pound and a half of ſugar of lead are added, and the whole often ſtirred for two days. On ſettling, a clear liquor is found at top which conſiſts of acetite of alumine, but ſtill containing much undecompoſed alum, and a denſe white ſediment remains at bottom which is ſulphat of lead. The clear liquor is the part uſed for the mordant, but previouſly two ounces of pearlaſh and as much chalk are added, more entirely to neutralize any exceſs of acid, and partly to decompoſe the ſolution; for though the mordant muſt be in a ſaline ſtate entirely to fix itſelf to the fibres of the cotton, it ſhould ſeem that the true intermede between the cotton and the dye is the alumine, and not the acids that hold it in ſolution, and hence the weaker the adheſion of theſe is to the alumine, and the ſtronger will be the triple union between the colour, the earth, and the cotton fibre.

The other mordant conſtantly in uſe with the printers is a ſolution of iron in vinegar, ſoured beer, pyroligneous acid, or other vegetable acids, and which therefore is chiefly an acetite of iron mixed with a portion of tartrite, perhaps gallat, and other ſalts of this metal.

To make theſe mordants fit for printing, and give them ſuch a conſiſtence as will enable them to dry in a figured pattern without running into the adjoining parts, they are thickened with paſte to the conſiſtence of jelly; and when to be uſed, this jelly is ſqueezed through a very fine ſieve by a particular and ſimple contrivance, on the ſurface of which it lies as a thin coating convenient to be transferred to the printing blocks.

The mordant, when naturally colourleſs, is a little tinged with Brazil wood (which being a very fugitive dye does not impair the general effect) that the workman may ſee the impreſſion on the cloth and fix the pattern with accuracy.

The inſtrument by which the impreſſion is given (or what anſwers to the types in the printing of books) is a piece of hard wood, generally holly, about a foot long, on which the pattern is carved, nearly as in wood engraving, and is ſtrengthened at the back with a thicker piece of oak glued on. The parts of the pattern that are to receive a large body of colour, and conſequently require a correſponding quantity of mordant, are given by pieces of old hat inlaid into the block which are found to take up the mordant in a more uniform way than any other material. Of late years alſo ſome of the finer patterns are given by ſheet-copper fixed on a block like fillagree work, which gives a finer and ſharper line to the figured pattern. Fine work is ſometimes given ſtill more expeditiouſly by engraved copper-plate and the rolling-preſs as in common picture engraving.

The general proceſs of the ſimple kind of calico-printing therefore is the following: the cotton cloth, previouſly bleached with alkali and much waſhing, and calendered to ſmooth the ſurface, is ſtretched on a long table covered with woollen cloth, when the printer firſt lays the block on the ſieve that contains the mordant, then applies it ſteadily on the cloth, and ſtrikes it a ſmart blow on the back with a wooden mallet to give a ſtrong impreſſion.

This he repeats ſucceſſively, each time carefully laying the block in the proper direction ſo as not to overlap the laſt impreſſion, till the whole is finiſhed.

In this way the patterns are impreſſed with one or more kinds of mordant as may be required, after which the cloth is ſtrongly dried in a ſtoved room, which both fixes the mordant more firmly to the cotton, and volatilizes much of the acetous acid in fumes very ſenſible to the ſmell. When dry, the cloth is taken to a ciſtern containing very warm water, in which cow-dung is diffuſed, and there it is worked about to diſſolve out the paſte and other ſuperfluous part of the mordant, ſufficient being yet left firmly united to the fibres of the cloth to fix the dye in the ſubſequent proceſs. The cloth is then rinced and thoroughly cleaned, after which it is dyed in the uſual way. The cloth comes out of the dying ciſtern entirely coloured (yellow for example when the dye has been weld) it is then again waſhed with water, boiled with bran and water, alternating with expoſure to air on the bleach-field, and other bleaching proceſſes, till at laſt all the colour of the ground has diſappeared, and that only remains which has been fixed to the pattern by the mordant.

The above is the ſimpleſt proceſs, that is, in which all the mordants are laid on firſt, and the colour is given by a ſingle dyeing afterwards, and by merely varying the mordants a conſiderable variety of ſhades may be given. Thus for example, if one pattern be printed with the aluminous mordant alone, a ſecond with a mixture of the former mordant with iron liquor, a third with iron liquor alone, and a fourth with iron liquor and galls, and the piece be afterwards dyed with quercitron or weld, and the ground bleached in the uſual manner, the firſt pattern will be of a pure yellow, the ſecond will be olive, the third of a dark drab colour, and the fourth nearly black, whilſt the ground will be white.

Cloth that has been thus printed with one courſe of colours is often ſubjected to a ſimilar proceſs for a different courſe with another dye, where the intended pattern requires a great variety of colours.

Thus when all the reds, purples, browns, &c. have been given by a courſe of madder, the cloth with part of the patterns thus finiſhed, may be made to undergo a courſe of mordants to be afterwards dyed with quercitron for other parts of the pattern. In this caſe however much judgment is required to employ only thoſe ſucceſſions which will not materially injure each other. It might be at firſt ſuppoſed that when a pattern dyed red (for example) with madder and an alum mordant came to be immerſed in a decoction of weld without any freſh mordant, that the former would not be at all affected by the latter, or at leaſt that the effect would ſoon be deſtroyed by bleaching; but this is not found to be altogether the caſe, for adjective colours appear to have alſo their *relative* affinities for mordants, therefore as a faſt madder red is a compound of madder and alumine, if madder has a leſs affinity for alumine than weld, the colour will be in part decompoſed, and ſome of the weld will diſplace a portion of the madder. Hence the colour will be changed into a triple compound of madder, weld, and alumine, and the dye proportionally altered. It appears therefore that in printing ſucceſſive courſes of colours attention ſhould be paid to print firſt thoſe whoſe affinities for the mordants are the ſtrongeſt, and finiſh with the weakeſt, unleſs indeed (which is ſometimes the caſe) the change produced by the intermixture of colours be a part of the deſired effect. But much remains to be done towards a rational explanation of the complicated affinities and mutual action of mordants and colouring matter, and of the apparently ſlight variations by which, however, the ſkilful printer is enabled to produce effects which at preſent a perſon could hardly hope to imitate without a large ſhare of practical experience.

Another part of calico-printing is the impreſſion of *colours*, for hitherto that of mordants only has been mentioned. In this caſe alſo, as in general dyeing, the ſubſtantive colours do not, and the adjective colours do, require to be previouſly mixed with their proper mordant. Pattern colours are applied either by the block (as the mordants are) or by pencilling or painting. In the latter caſe the colour is thickened not with paſte but with gum arabic or ſenegal, and it is applied with a camel's hair bruſh. The pencilled colours require no further dyeing operation, and are only finiſhed by waſhing and drying, ſo that it is uſually the laſt parts of the pattern that are given in this way.

Indigo is the only ſubſtantive colour uſed for pencilling, but here a very great difficulty preſents itſelf; for indigo (as already mentioned in deſcribing the blue dye) is only a faſt colour when in its diſoxygenated ſtate, in which it is yellow or green; but when much expoſed to air, as can hardly be avoided in the ſlow and minute proceſs of pencilling, part of it returns to the blue or oxygenated ſtate before it has properly fixed itſelf on the ſtuff, and this por-

tion is carried away in the ſubſequent waſhing. It is therefore very ſeldom that the pattern of a whole piece can be indigo-penciled with the ſame uniformity with which ſome of the other colours are given. The ſolution uſed for this purpoſe is uſually made of a large proportion of indigo diſſolved in potaſh, rendered cauſtic by lime, to which is added orpiment for the deoxygenation of the indigo. This latter effect is alſo often produced wholly or in part, by the cheaper kind of raiſins. The ſolution is then thickened by gum, and ſhould be kept in a cloſe ſtopped veſſel, and no more expoſed to air than is neceſſary for immediate uſe.

This indigo-blue is alſo often pencilled upon figures previouſly dyed yellow in order to produce a permanent green, but with ſome little injury to the yellow ground by the cauſtic alkali contained in the indigo ſolution.

Adjective colours are ſometimes mixed with their proper mordant, and uſed in this ſtate for pencilling without any other preparation. Such a mixture has therefore the effect of a ſubſtantive colour. Thus if a very ſtrong decoction of weld or quercitron is added to a mixture of alum and ſugar of lead, and the whole duly thickened, a yellow of a certain degree of durability is formed at once, and may be printed or pencilled on a white ground to produce a yellow, on an indigo ground to give a green, on a red madder ground to give an orange and the like.

It is found however that adjective colours when firſt mixed with their mordants, and then applied to cotton, have very little durability compared to that of the method of firſt applying the mordant thoroughly, and then the colour. This difference holds good in the general as well as topical dyeing of cotton and linen with all adjective colours, as has already been fully deſcribed, though with regard to wool it appears to be often a matter of indifference as to the fixity of the colour, whether the mordant and the dye are applied ſeparately or united. Thus woollen cloth may be dyed with cochineal and tin, apparently equally well in one as in two operations. But as this does not hold with cotton it ſtill remains a great object in calico-printing to diſcover ſome method of pencilling adjective colours ſo as to be ſufficiently durable. It is alſo an additional difficulty to this object that the pencilled colours always require a very full body of colour, being generally applied rather as finiſhing touches to the pattern than conſtituting any very large portion of it.

In many caſes parts of the pattern itſelf are required to be white. Sometimes this may be done ſimply in the way that the ground is left white, that is by leaving theſe parts untouched by any mordant, ſo that when the whole is dyed with an adjective colour, ſubſequent waſhing and bleaching will deſtroy the dye on theſe untouched parts. This plan however is obviouſly inadmiſſible when the general dye is given by a ſubſtantive colour as indigo. In ſuch caſes ſome kind of covering muſt be applied to the white pattern parts to protect them from the dye, and hinder it from penetrating. In the Eaſt Indies wax is often uſed topically on the white parts for this purpoſe. In this country a mixture of pipe clay and paſte is ſometimes uſed. In theſe caſes the cold indigo vat is of particular ſervice, as the covering for the white is much leſs liable to be diſſolved out, than in the uſual way of dyeing in a heated bath.

But in the common method of producing white with adjective colours, the ſmaller parts of the pattern are ſeldom ſo well defined and thoroughly bleached as to render the work perfect. With every care ſome part of the adjoining printed mordant will often ſpread a little beyond its proper limits, and occaſion a permanent ſoil on the white, beſides that the removing ſome ſtains by bleaching, particularly thoſe from the weld bath, is tedious and difficult. To remedy this therefore, and to give a perfectly clear and well defined pattern white to the parts without mordant, which ſo much improves the general effect, the bleaching power of *acids* has lately been much reſorted to. Moſt of the acids poſſeſs this power, but the ſtronger mineral acids are ſo liable to affect the texture of the cotton when ſufficiently ſtrong, that they cannot be employed. Recourſe therefore has been had to the ſtronger vegetable acids, and of theſe the *Citric*, either in its cryſtallized ſtate, or merely as lemon juice concentrated by boiling, holds the firſt place, and this article has of late years been conſumed by the printers of this country to a vaſt amount. It is uſually applied by the block like the common mordants. The particulars of the preparation of the *Citric* acid are deſcribed under that article.

For ſome further obſervations on the nature of colouring matter ſee the article *Extract*.

E

EARTH. *Terre*, Fr. *Erde*, Germ.

While chemiſtry was under the dominion of fancy and metaphyſics, before the eſtabliſhment of the maxim that facts are to precede and ſerve as the baſis of all reaſonings in natural ſcience, it was imagined that all material ſubſtances were ultimately reſolvable into four ſimple bodies, viz. air, fire, water, and earth, which were hence called the four elements. The two firſt were avowedly almoſt wholly unknown, moſt liquids were ſuppoſed to be modifications of the third, and the ſolid particles of bodies were attributed to the laſt. Earth in this extended ſenſe was chiefly characterized by the properties of hardneſs and ſolidity, and was ſubdivided into various ſpecies, according to the ſuppoſed modifications that it underwent. Thus the claſs of combuſtible bodies was imagined to contain more or leſs of an inflammable earth; the various metals were conſidered as abounding with a metallic or mercurial earth, and ſo on of the other great claſſes into which ſolids are divided. Theſe ſeveral earths however were conſidered as only modifications of the primitive elementary one. Modern chemiſtry, though it has retained the term in a much more reſtricted ſenſe than it was applied formerly, has yet included under it a ſufficiently heterogeneous aſſemblage of bodies; a conſiderable portion of which may much more properly be conſidered as belonging to the claſs of alkalies.

The earths that are at preſent known are nine in number, namely, Silex, Zircon, Alumine, Glycine, Yttria, Barytes, Strontian, Lime, Magneſia. When purified by art from all foreign mixture they agree in the following properties. 1. they are of a ſnow-white colour; 2. are infuſible by a very intenſe heat; 3. are not reducible to the metallic ſtate by being heated in contact with combuſtible matter. Of theſe nine earths however the four laſt have all the properties of alkalies (whence indeed they have ſometimes been called alkaline earths) not differing from potaſh or ſoda ſo much as theſe do from ammonia. If therefore we were to confine the term earth to the five firſt, this double advantage would accrue from the arrangement, that the two claſſes of alkalies and earths would each admit of a genuine chemical definition, which they both equally want at preſent.

If ſuch an arrangement were adopted, the remaining earths would be thus characterized. They are infuſible, and inſoluble in water, and have neither taſte nor ſmell: they exhibit neither acid nor alkaline characters: they combine with acids and with alkalies either pure or carbonated: they have no action on metallic ſubſtances and are incapable of aſſuming the reguline form.

A conſiderable ſtir was made a few years ago in Hungary, by the pretended metallization of ſeveral of the earths by M. M. Ruprecht and Tondi, till their experiments were repeated by Klaproth and others, and ſhown to be entirely fallacious. The chemiſts firſt mentioned took a ſmall quantity of any earth, barytes for example, and having beaten it up with a little water and charcoal, ſmeared it on the inſide of a Heſſian crucible; the cavity was then filled with powdered charcoal, and at the top of all was placed a layer of bone-aſh; a cover being then luted on, the crucible was expoſed for three-quarters of an hour to a blaſt furnace, in which it was heated almoſt to a ſtate of paſty fuſion. When the contents of the crucible were examined, the barytes was found in part melted with the earth of the crucible, and containing from 2 to 4 per cent. of brittle metallic globules, which were ſuppoſed to have originated from a decompoſition of part of the barytes. Theſe globules however on analyſis by Klaproth, proved to be nothing more than phoſphuret of iron; the metallic part doubtleſs originating from the iron contained in the earth of the crucible, and the phoſphorus from the bone-aſh by means of the charcoal. That this is the true explanation of the appearance is evident from another experiment of Klaproth, in which he repeated the proceſs of Ruprecht, only ſubſtituting a porcelain for a Heſſian crucible; but the earth of this crucible contained no iron, and there was not the ſlighteſt appearance of metallic globules in the barytes which it contained. Further, the experiment was again repeated in a Heſſian crucible, only leaving out the barytes, and the globules made their appearance as plentifully as when the barytes was preſent. [a]

EARTHENWARE. See POTTERY.

EAU DE LUCE. This is a ſcented ſavonule compoſed chiefly of liquid ammonia and oil of amber, and forms a white milky fluid. Theſe two ingredients however, even if mixed by long agitation in a vial ſo as apparently to be perfectly combined, after ſtanding for a ſhort time

[a] An. de Chim. x. p. 275.

ſeparate from each other into two liquids, the upper of which is the principal part of the oil little altered, and the lower is the ammonia, retaining juſt enough of the oil to give it a wheyiſh appearance. The following is recommended by Macquer [a] as an efficacious method of preparing permanent Eau de luce.

Take four ounces of rectified ſpirit of wine and diſſolve in it ten or twelve grains of white ſoap; filter this ſolution, and then diſſolve in it a dram of rectified oil of amber, and filter again: mix with this a few drops of ſtrong liquid ammonia and ſhake the whole well together in a vial; then add a little more ammonia, and ſo on gradually till the liquor becomes of the conſiſtence of cream. This method however often fails to produce the deſired effect, the compound ſpontaneouſly ſeparating after a few days: hence various other additions have been made by druggiſts with greater or leſs ſucceſs, and ſome of the beſt of all are kept in a conſiderable degree ſecret.

The goodneſs of the following method is atteſted by an anonymous correſpondent in Nicholſon's journal. [b]

"Digeſt ten or twelve grains of the whiteſt "pieces of maſtich ſelected for this purpoſe and "powdered, in two ounces of alcohol, and "when nearly diſſolved add twenty grains of "elemi. When both the reſins are diſſolved "add ten or fifteen drops of rectified oil of "amber, and fifteen or twenty of eſſence of "bergamot; ſhake the whole well together and "let the fæces ſubſide. The ſolution will be "of a pale amber colour. It is to be added in "very ſmall portions to the beſt aqua ammoniæ "puræ until it aſſumes a milky whiteneſs, "ſhaking the vial well after each addition." If upon the addition of the firſt drop or two of the tincture a denſe opake coagulated precipitate is formed, it is too ſtrong and muſt be diluted with alcohol. About one part of the tincture to four of the ammonia will produce the required opacity.

EDULCORATION. *Abſuſſen*, Germ.

This term is applied in chemiſtry to the proceſs of waſhing out from a precipitate any exceſs of acid or alkali or compound ſalt that may adhere to it. The uſual way is to place the precipitate on a filter, and when nearly all the liquor has drained away from it, to fill up the filter again with clean and pure water, either hot or cold, and as ſoon as this has paſſed through to replace it with freſh, till the laſt portions that drain are wholly taſteleſs and produce no change on turmeric or litmus-paper. This method however is often leſs effectual, and is always more tedious than the proceſs which is had recourſe to at preſent. When the precipitate is depoſited, inſtead of throwing it on a filter pour it into a large ſilver crucible and boil it with ſome water; after this withdraw it from the fire, allow it a few minutes to ſubſide, and draw off the clear liquor; then add freſh water to the reſidue and again boil it, and proceed thus till all ſoluble impurities are got rid of. A ſingle half-hour thus employed will finiſh more work than a whole day in the common method, and the neceſſary loſs upon the precipitate is conſiderably leſs, which is a circumſtance of no ſmall importance to the accuracy of an analyſis.

EFFERVESCENCE. *Aufbrauſen*, Germ.

Effervescence is a rapid diſengagement of gas taking place within a liquid. In conſequence of this numerous bubbles riſe to the ſurface, forming a head of froth and burſting with a hiſſing noiſe. There is ſome external reſemblance between effervescence and fermentation, only the latter proceſs is much ſlower and more durable, hence it was that the ancient chemiſts applied the term fermentation to all the phenomena which are at preſent denoted by effervescence, and this miſapplication of the term irreſiſtibly induced them to explain the two proceſſes by the ſame theory. Hence ſalt of tartar, of wormwood, and in ſhort all the mild alkalies, as well as the ſeveral varieties of carbonated lime, were ranked as fermentable bodies, and the muriatic, nitric, and ſulphuric acids, the addition of which produced in them effervescence or fermentation, were called ferments; and as in theſe caſes the ferment was an obvious acid, ſo they imagined that all real ferments were alſo eſſentially acids, but with their properties maſked and obtunded by mixture with mucilage, &c.

The gas of effervescence is produced by ſingle or double elective affinity; in the former caſe it is for the moſt part carbonic acid, in the latter it is either nitrous gas or hydrogen. It is manifeſt that the gas muſt have little or no affinity with the fluid in which it is immerſed, in order to produce effervescence, hence it is that although carbonic and muriatic acids are both gaſſes, and are both extricated from their alkaline combinations by ſulphuric acid, yet a ſolution of carbonat of potaſh in water ſhall produce a vehement effervescence with ſulphuric acid, while muriat of potaſh in the ſame cir-

[a] Chim. Dict. art Eau de Luce.

[b] Nicholſon's Jour. 4to. vol i. p. 167.

cumſtances ſhall occaſion none at all, the carbonic acid having little or no affinity for water acidulated by ſulphuric acid, while the muriatic acid will combine with the ſame very readily.

EFFLORESCENCE. *Beſchlag*, Germ.

Efflorescence is the formation of a powdery cruſt, or of minute ſpicular cryſtals on the ſurface of any ſubſtance. It is applied to two diſtinct phenomena, which it is of conſequence to be aware of. Salts are either unalterable in the air, or they attract part of its moiſture and are reſolved into a fluid, or they yield part of their water of cryſtallization to the air, and are in conſequence firſt ſuperficially, and afterwards entirely reduced to powder. This effect, at leaſt in its commencement, is called efflorescence, and ſuch ſalts are denominated efflorescent: but there is another kind of efflorescence wholly diſtinct from this, as when we ſpeak of the efflorescence of iron pyrites or of new mortar; in theſe caſes it implies the appearance of a ſuperficial covering of minute hair-like cryſtals, and is occaſioned by the chemical changes that take place on the ſurface of the ſubſtance where theſe cryſtals appear. Thus ſulphuret of iron is changed by efflorescence into ſulphat of iron or green vitriol: whereas ſulphat of ſoda when ſubjected to the efflorescence firſt mentioned, although changed in form remains the ſame in compoſition, except that it has loſt part of its water. The one deſtroys cryſtals, the other produces them.

EGYPTIAN PEBBLE. See JASPER.

EISENKIESEL. See QUARTZ.

ELASTIC BITUMEN. See BITUMEN.

ELASTIC GUM. See CAOUTCHOUC.

ELEMENTS. *Uranfange*, Germ.

Modern chemiſtry does not acknowledge any particular number of elements, but freely admits into this claſs all ſubſtances that have not hitherto been decompoſed. An element therefore is merely one of the laſt reſults of chemical analyſis; and in denominating ſubſtances elementary or ſimple, we look upon them as ſuch only with regard to the preſent ſtate of chemical ſcience. It is not probable that any one of the ſimpleſt bodies with which we are acquainted is really and eſſentially elementary, and it is at beſt needleſs to enter into an enquiry in which there are no facts to reſt on for ſupport.

ELEMI. The reſin known by this name, improperly called gum elemi, is ſuppoſed to be the produce of a large tree, arranged in the Linnæan ſyſtem under the name Amyris Elemifera, and concerning which we know little or nothing, except that it is a native of Carolina and the warmer parts of America. But the true elemi, according to Geoffroy, comes from Ethiopia.

The colour of this reſin is a light yellow inclining to green; it is firm on the outſide, but internally is ſomewhat ſoft and adheſive; it has a bitteriſh flavour and a grateful fragrant odour not very unlike that of ſweet fennel ſeeds. It comes to us in cylindrical pieces or cakes, covered with palm-leaves.

When diſtilled in a water-bath, elemi affords about $\frac{1}{16}$ of eſſential oil, in which all the fragrance of the ſubſtance reſides, the remaining reſin being entirely inodorous and brittle. Sixteen ounces of elemi give out to hot water about three drams of extract, and of the remainder fifteen ounces appear to be reſin.

Elemi is a ſcarce and dear ſubſtance; it is uſed occaſionally in medicine as a liniment, and is employed in the arts as an ingredient in ſome varniſhes.

ELUTRIATION. *Verwaſchen*, Germ.

This term is nearly ſynonymous with *waſhing* or *waſhing over*. It is a method of ſeparating ſubſtances of different ſpecific gravities from each other by means of water. For this purpoſe the mixture is ſtirred up briſkly with water, and when the heavier particles have again fallen to the bottom, the turbid water containing the lighter ones ſtill ſuſpended is poured off into another veſſel. By this ſimple method, a perſon accuſtomed to the buſineſs will ſeparate three or four ſubſtances from each other with ſurprizing exactneſs and expedition.

ELIQUATION. See SILVER.

EMERALD.[a] Of this mineral we may diſtinguiſh the two following ſubſpecies.

1. Emerald. *Emeraude verte*, Hauy. *Schmaragd*, Werner.

The characteriſtic colour of emerald is pure priſmatic green of various degrees of intenſity; the deep coloured varieties paſs occaſionally into graſs and verdigris green, and the lighter ones into greeniſh white. It has hitherto been met with only cryſtallized. Its primitive figure is a regular hexahedral priſm, the lateral planes of which are ſmooth, and the terminal planes rough. 1. Sometimes the lateral edges are replaced by ſecondary planes, forming a dodecahedral priſm. 2. Or the ſolid angles are replaced by ſmall triangular facets. 3. Or the edges adjoining to the baſe are replaced by planes inclined towards the axis of the cryſtal, the junction of which forms a terminal trun-

[a] Hauy, Brochant, Jameſon.

cated hexahedral pyramid. 4. Sometimes the ſolid angles at the common baſe of the priſm and its terminal pyramid (var. 3.) are replaced by ſmall rhombs. 5. Sometimes the ſecondary planes of var. 3 are very narrow, ſo that the terminal edges appear only bevilled. The length of the priſms ſeldom greatly exceeds their diameter. The cryſtals are middle-ſized and ſmall, very rarely large, the greateſt that has yet been found is about 6 inches long and 2 inches in diameter: they are always implanted and in cluſters. The internal luſtre is vitreous and ſhining, ſometimes brilliant. Its fracture is ſmall and imperfectly conchoidal, paſſing into obſcurely foliated in four directions correſponding with the faces of its integrant molecule, which is an equilateral triangular priſm, the lateral planes of which are ſquares. It is tranſparent or tranſlucent, and exhibits a double refraction. Its hardneſs is ſomewhat ſuperior to that of quartz, which it ſcratches with difficulty. Sp. gr. 2.72 to 2.77.

It is fuſible but with difficulty before the blowpipe into a whitiſh glaſs; it melts eaſily without efferveſcence by borax. Its conſtituent parts, according to Vauquelin and Klaproth, are

	Vauq.		Klap.
Silex	64.5	—	69.
Alumine	16.	—	15.
Glycine	13.	—	12.5
Lime	1.6	—	0.25
Oxyd of chrome	3.25	—	0.25
Oxyd of iron	0.	—	1.
Water	2.	—	0.
	100.35		98.

It occurs in veins paſſing through argillaceous ſchiſtus, and is accompanied by calcareous ſpar, felſpar, quartz, and iron pyrites. It is found at preſent only in Peru in the valley of Tunia or Tomana, between the mountains of New Granada and Pompayan, and in the province of Manta. Previous to the diſcovery of America, the emeralds of Europe were procured from Ethiopia.

Emerald is reckoned among the gems, and when of a fine colour and without flaws is highly eſteemed. The large emeralds ſpoken of by various writers, ſuch as that in the Abbey of Reichenau, of the weight of 28 pounds, and which formerly belonged to Charlemagne, appear to be either green glaſs, green fluor, or praſe. The moſt magnificent ſpecimen of genuine emerald was preſented to the church of Loretto by one of the Spaniſh kings; it conſiſts of a maſs of white quartz thickly implanted with emeralds more than an inch in diameter.

2. Beryl, or Aquamarine. *Emeraude vert-bleuâtre*, Hauy. *Edler Beril*, Werner.

Its colour is either mountain-green paſſing into apple-green, oil-green, greeniſh-white, honey yellow and wine yellow (the chryſolite of ſome authors), or celandine-green paſſing into ſmalt, ſky, and very rarely ultramarine blue. Its colours are almoſt always pale: when two exiſt in the ſame cryſtal they generally are arranged in alternate layers. The primitive form and varieties of cryſtallization are thoſe which have been already deſcribed in the preceding ſubſpecies. The actual and proportionate length of the priſms in beryl is much greater than in emerald; the lateral planes are ſtriated longitudinally, ſo as ſometimes to give the priſm a cylindrical appearance, and the terminal ones are ſmooth: the joints perpendicular to the axis are generally very diſtinct, moſt commonly they are plane ſurfaces, but ſometimes the joints like thoſe of articulated baſalt are formed by a convex protuberance let into a cup-ſhaped concavity; another ſingular analogy between theſe two widely different minerals is, that a priſm which at its lower end is ſolid, terminates occaſionally in a bruſh-like extremity, compoſed of numerous ſmall priſms. Sometimes a joint is ſo diſpoſed that it is no longer perpendicular to the axis of the priſm, in conſequence of which an elbow is produced, as if the priſm had been broken acroſs and the pieces ill cemented together again. Sometimes again the axis of the priſms is perforated. The ſize of the cryſtals varies from capillary to 18 inches long by three or four in diameter. Its external luſtre is ſhining and gliſtening; internally it has a brilliant vitreous luſtre. Its croſs fracture is between uneven and ſmall imperfectly conchoidal: its longitudinal fracture is foliated. It is commonly tranſparent paſſing into tranſlucent. Its hardneſs is the ſame as that of the emerald. Sp. gr. 2.68 to 2.72. It becomes very electric by friction.

Its conſtituent parts according to Vauquelin and Roſe, are

	Vauq.		Roſe.
Silex	68	—	69
Alumine	15	—	14
Glycine	14	—	14
Lime	2.	—	0
Oxyd of iron	1.	—	1
	100.		98.

Beryl occurs imbedded in primitive rocks, alſo in veins accompanied by quartz, felſpar, fluor ſpar, garnet, mica, and topaz. The fineſt ſpecimens come from Daouria in Siberia: it is alſo found in the Uralian mountains, in Braſil, in Saxony, near the village of Barat in the ſouth of France, whence very large but ill-coloured cryſtals have been procured, and occaſionally in the higheſt mountains of Aberdeenſhire. It is ranked by courteſy among the gems, but is in very ſmall eſtimation.

EMERY. See CORUNDUM.

EMETIC TARTAR. See ANTIMONY, *Tartrite of*.

EMPYREUMA. *Brenzliche beſchaffenheit*, G. Empyreuma is that peculiar and moſtly diſagreeable odour and taſte which almoſt all animal and vegetable ſubſtances contract while decompoſing by fire, eſpecially in cloſe veſſels. An oil appears to be generated during the dry diſtillation of all organized bodies, and this when ſcorched ſeems to be the immediate cauſe of empyreuma.

EMPYREUMATIC ACID. See ACETOUS ACID *empyreumatic*.

EMPYREUMATIC OIL. See OIL.

EMULSION. *Körnermilch*, *Saamenmilch*, G. An emulſion is a white milky-looking fluid, cauſed by an imperfect temporary combination of oil with water by means of mucilage, fecula, gluten, gelatin, and the like. All the oily farinaceous ſeeds, ſuch as nuts, almonds, linſeed, hemp-ſeed, muſtard-ſeed, &c. form an emulſion by ſimple trituration with water; yolk of egg, which is a natural compound of oil and albumen, makes a ſimilar emulſion, and theſe are much ſlower in undergoing ſpontaneous ſeparation than thoſe emulſions all the ingredients of which are put together by art, as when we triturate together oil and gum-water, yet even theſe by continued agitation may be made to enter into pretty intimate combination.

ENAMEL. *Email*; Fr. *Schmeltzwerk*; Germ.

The delicate and beautiful art of enamelling conſiſts in the application of a ſmooth coating of vitrified matter (tranſparent or opake, and with or without colour, figures, and other ornaments) to a bright poliſhed metallic ſubſtance. It is therefore a kind of varniſh made of glaſs, and melted upon the ſubſtance to which it is applied, and affording a fine uniform ground for an infinite variety of ornaments which are alſo fixed on by heat.

The general principles on which enamelling is founded are on the whole very ſimple, but perhaps there is none of all the chemico-mechanical arts which requires, for the finer parts, a greater degree of practical ſkill and dexterity, and of patient and accurate attention to minute proceſſes.

The concealment obſerved by thoſe who profeſs this art is proportioned to the difficulty of acquiring it; the general chemiſt muſt therefore content himſelf with the general principles of enamelling, and the detail of thoſe particulars that are commonly known.

Though the term enamelling is uſually confined to the ornamental glazing of metallic ſurfaces, it ſtrictly applies to the glazing of POTTERY or porcelain, the difference being only that in the latter the ſurface is of baked clay. With regard to the compoſition of coloured enamels (which are all tinged by different metallic oxyds) a very general account of the ſubſtances uſed will ſuffice in this place, and the reſt of the ſubject may be properly referred to the article of coloured GLASS. The enamelling on metals therefore will only be noticed in this place.

The only metals that are enamelled are gold and copper, and with the latter the opake enamels are only uſed. Where the enamel is tranſparent and coloured, the metal choſen ſhould be of that kind as not only to have its ſurface unalterable when fully red-hot, but alſo to be in no degree chemically altered by the cloſe contact of melted glaſs, containing an abundance of ſome kind of metallic oxyd. This is the chief reaſon why coloured enamelling on ſilver is impracticable, though the brilliance of its ſurface is not impaired by mere heat, for if (for example) an enamel made yellow with oxyd of lead or antimony is laid on a ſurface of bright ſilver, and kept melted on it for a certain time, the ſilver and the enamel act on each other ſo powerfully that the colour ſoon changes from a yellow to an orange, and laſtly to a dirty olive. Copper is equally altered by the coloured enamels, ſo that gold is the only metal which can bear the long contact of the coloured glaſſes at a full red heat, without being altered by them.

The ſimpleſt kind of enamel is that fine white opake glaſs which is applied to the dial-plate of watches. The proceſs of laying it on (which may ſerve as a general example of the art) is the following:

A piece of thin copper ſheet hammered of the requiſite convexity is firſt accurately cut out, a hole drilled in the middle for the axis of

the hands, and both the ſurfaces made perfectly bright with a ſcratch bruſh.

A ſmall rim is then made round the circumference with a thin braſs band riſing a little above the level, and a ſimilar rim round the margin of the central hole. The uſe of theſe is to confine the enamel when in fuſion, and keep the edges of the plate quite neat and even. The ſubſtance of the enamel is a fine white opake glaſs, the material of which will be preſently mentioned. This is bought in lump by the enamellers, and is firſt broken down with a hammer, then ground to a ſufficiently fine powder, with ſome water in an agate mortar; the ſuperfluous water being then poured off, the pulverized enamel remains of about the conſiſtence of wetted ſand, and is ſpread very evenly over the ſurface of the copper plate by many dexterous manipulations. On moſt enamellings, and eſpecially on this it is neceſſary alſo to counter enamel the under or concave ſurface of the copper plate to prevent its being drawn out of its true ſhape by the unequal ſhrinking of the metal and enamel on cooling. For this kind of work the counter-enamel is only about half the thickneſs on the concave as on the convex ſide. For flat plates the thickneſs is the ſame on both ſides.

The plate covered with the moiſt enamel powder is warmed and thoroughly dried, then gently ſet upon a thin earthen ring that ſupports it only by touching the outer rim, and put gradually into the red-hot muffle of the enameller's furnace. This furnace is conſtructed ſomewhat like the aſſay furnace, but the upper part alone of the muffle is much heated, and ſome peculiarities are obſerved in the conſtruction to enable the artiſt to govern the fire more accurately.

The preciſe degree of fire to be given here as in all enamelling, is that at which the particles of the enamel run together into an uniform paſty conſiſtence, and extend themſelves evenly over the ſurface ſhewing a fine poliſhed face, carefully avoiding on the other hand ſo great a heat as would endanger the melting of the thin metallic plate. When the enamel is thus ſeen to *ſweat down*, as it were, to an uniform gloſſy glazing, the piece is gradually withdrawn and cooled, otherwiſe it would fly by the action of the cold air.

A ſecond coating of enamel is then laid on and fired as before, but this time the fineſt powder of enamel is taken, or that which remains ſuſpended in the waſhings. It is then ready to receive the figures and diviſion marks, which are made of a black enamel, ground in an agate mortar with much labour to a moſt impalpable powder, worked up on a pallet with oil of lavender, or ſpike, and laid on with an extremely fine hair bruſh. The plate is then ſtoved to evaporate the eſſential oil, and the figures burnt in as before. The poliſhing with tripoli and minuter parts of the proceſs need not be here mentioned.

If the enamel be chipped off a dial plate (which may be done with the utmoſt eaſe by bending it backwards and forwards, as the adheſion between the metal and glazing is very ſlight) the part immediately in contact with the copper will be found deeply and nearly uniformly browned, which ſhews how unfit copper alone would be for the tranſparent enamels.

The regulation of the fire appears to be the moſt difficult of all the parts of this nice proceſs, particularly in the fine enamelling of gold for ornamental purpoſes, of deſigns, miniatures and the like, where three, four, or ſometimes five ſeparate firings are required. If the heat is too low the enamel does not ſpread and vitrify as it ought; if too high, it may be enough to melt the metal itſelf, whoſe fuſing point is but a ſmall ſtep above that of the enamel, or elſe (what is an equal mortification to the artiſt) the delicate figures, laid on with ſo much care and judgment, melt down in a moment, and the piece exhibits only a confuſed aſſemblage of lines and fragments of deſigns.

The exact compoſition of the opake white enamel is a matter of conſiderable importance, and is procured by the enamellers from perſons whoſe buſineſs it is to prepare it. A good enamel of this kind, fit to be applied both to porcelain and metals, ſhould be of a very clear fine white, ſo nearly opake as only to be tranſlucent at the edges, and at a moderate red heat it ſhould run into that kind of paſte, or imperfect fuſion which allows it to extend itſelf freely and uniformly, and to acquire a gloſſy even ſurface, without however fully melting into a thin glaſs. The opake white of this enamel is given by the oxyd of tin, which poſſeſſes, even in a ſmall proportion, the property of rendering vitreſcent mixtures white and opake, or in ſtill leſs proportion, milky, and, when otherwiſe coloured, opaleſcent. The oxyd of tin is always mixed with three or four times its quantity of oxyd of lead, and it appears neceſſary that the metals ſhould be previouſly mixed by melting, and the alloy then calcined.

* An. Chim. tom. 34.

The following are the directions given by Clouet for the compoſition of this enamel.[a] Mix 100 parts of pure lead with from 20 to 25 of the beſt tin, and bring them to a low red heat in an open veſſel. The mixture then burns nearly as rapidly as charcoal and oxidates very faſt. Skim off the cruſts of oxyd, ſucceſſively formed, till the whole is thoroughly calcined. It is better then to mix all the ſkimmings and again heat as before till no flame ariſes from them, and the whole is of an uniform grey colour. Take 100 parts of this oxyd, 100 of ſand, and 25 or 30 of common ſalt, and melt the whole in a moderate heat. This gives a greyiſh maſs, often porous and apparently imperfect, but which however runs to a good enamel when afterwards heated. This is the enamel uſed for porcelain, but for metals and finer works the ſand is previouſly calcined in a very ſtrong heat with a fourth of its weight, or, if a more fuſible compound is wanted, as much of the oxyd of tin and lead as of ſalt is taken, and the whole melted to a white porous maſs. This is then employed inſtead of the rough ſand as in the above-mentioned proceſs. The above proportions however are not invariable, for if more fuſibility is wanted the doſe of oxyd is encreaſed, and that of the ſand diminiſhed, the quantity of common ſalt remaining the ſame. The ſand employed in this proceſs according to M. Clouet is not the common ſort however fine, but a micaceous ſand, in which the mica forms about one-fourth of the mixture.

Neri in his valuable treatiſe on glaſs-making has given long ago the following proportions for the common material of all the opake enamels, which Kunckel and other practical chemiſts have confirmed. Calcine 30 parts of lead with 33 of tin, with the precautions mentioned above. Take of this calcined mixed oxyd 50 lb. and as much of powdered flints (prepared by being thrown into water when red-hot, and then ground to powder) and 8 ounces of ſalt of tartar, melt the mixture in a ſtrong fire kept up for 10 hours, after which reduce the maſs to powder. This is the common material for the opake enamels, and is of a grey white. To make this fine enamel quite white, mix 6 lb. of this material with 48 grains of the beſt black oxyd of manganeſe, and melt in a clear fire. When fully fuſed throw it into cold water, then remelt and cool as before two or three times till the enamel is quite white and fine. Kunckel obſerves on this proceſs, that he tried it without the oxyd of manganeſe, but the enamel inſtead of being milk-white was blueiſh and not good, ſo that there is no doubt but that this oxyd is highly important. If too much is uſed the enamel becomes of a roſe-purple. For further obſervations on the uſe of manganeſe in vitrefcent mixtures, ſee the article GLASS.

Coloured enamels are compoſed of a common baſis, which is a fuſible mixture of vitrifiable materials, and of ſome metallic oxyd. In general the coloured enamels are required to be tranſparent, in which caſe the baſis is a kind of glaſs compoſed of borax, ſand, and oxyd of lead, or other vitreſcent mixtures, in which the proportion of ſaline or metallic flux is more or leſs according to the degree of heat that the colouring oxyd will bear without decompoſition. When the coloured enamel is to be opake or opaleſcent, a certain portion of the white opake enamel, or of the oxyd of tin, is added to the mixture. The moſt beautiful and coſtly colour known in enamelling is an exquiſitely fine rich red with a purpliſh tinge, given by the ſalts and oxyds of gold, eſpecially the purple precipitate formed by tin in one form or other, and nitro-muriat of gold, and alſo by the fulminating gold. This beautiful colour requires much ſkill in the artiſt to be fully brought out. It is ſaid that when moſt perfect it ſhould come from the fire quite colourleſs, and afterwards receive its colour by the flame of a candle. Gold colours will not bear a violent fire.

Other and commoner reds are given by the oxyd of iron, but this requires the mixture of alumine or ſome other ſubſtance refractory in the fire, otherwiſe at a full red heat the colour will degenerate into black.

Yellow is given either by the oxyd of ſilver alone, or by the oxyds of lead and antimony, with ſimilar mixtures to thoſe required for iron. The ſilver is as tender a colour as gold, and readily injured or loſt in a high heat.

Green is given by the oxyd of copper, or it may alſo be produced by a mixture of blue and yellow colours.

Blue is given by cobalt, and this ſeems of all enamel colours the moſt certain, and eaſily manageable.

Black is produced by a mixture of cobalt and manganeſe.

Under the article of coloured GLASSES this ſubject will be noticed more at length.

The reader may conceive how much the difficulties of this nice art are increaſed when the object is not merely to lay an uniform coloured glazing on a metallic ſurface, but alſo to paint that ſurface with figures and other deſigns that require extreme delicacy of outline, accuracy of

[a] Art de la Verrerie.

ſhading, and ſelection of colouring. The enamel painter has to work, not with actual colours, but with mixtures which he only knows from experience will produce certain colours after the delicate operation of the fire; and to the common ſkill of the painter in the arrangement of his pallet and choice of his colours the enameller has to add an infinite quantity of practical knowledge of the chemical operation of one metallic oxyd on another, the fuſibility of his materials, and the utmoſt degree of heat at which they will retain not only the accuracy of the figures which he has given, but the preciſe ſhade of colour which he intends to lay on.

Painting in enamel requires a ſucceſſion of firings; firſt of the ground which is to receive the deſign, and which itſelf requires two firings, and then of the different parts of the deſign itſelf. The ground is laid on in the ſame general way as the common watch-face enamelling already deſcribed. The colours are the different metallic oxyds melted with ſome or other vitreſcent mixture and ground to extreme fineneſs. Theſe are worked up with an eſſential oil (that of ſpike is preferred, and next to it oil of lavender) to the proper conſiſtence of oil colours, and are laid on with a very fine hair bruſh. The eſſential oil ſhould be very pure, and the uſe of this rather than any fixed oil is probably that the whole may evaporate compleatly in a moderate heat, and leave no carbonaceous matter in contact with the colour when red-hot, which might affect its degree of oxidation and thence the ſhade of colour which it is intended to produce.

As the colour of ſome vitrified metallic oxyds (ſuch as that of gold) will ſtand only at a very moderate heat, whilſt others will bear, and even require, a higher temperature to be properly fixed, it forms a great part of the technical ſkill of the artiſt to apply the different colours in proper order; fixing firſt thoſe ſhades which are produced by the colours that will endure the higheſt heat, and finiſhing with thoſe that demand the leaſt heat. The outline of the deſign is firſt traced on the enamel, ground and burnt in; after which the parts are filled up gradually with repeated burnings, to the laſt and fineſt touches of the tendereſt enamel.

Tranſparent enamels are ſcarcely ever laid upon any other metal than gold, on account of the diſcoloration produced by other metals, as already explained. If however copper is the metal uſed, it is firſt covered with a thin enamel coating, over which gold leaf is laid and burnt in, ſo that in fact it is ſtill this metal that is the baſis of the ornamental enamel.

With regard to the vaſt number of important minutiæ in the ſelection and order of applying the colours, the management of the fire, &c. &c. almoſt the whole of what is known on this ſubject is confined to the practical artiſt, nor could this knowledge, if obtained, intereſt the general reader.

ENS MARTIS. A name given by the old chemiſts to ſal-ammoniac ſublimed with iron filings, and therefore conſiſting of muriat of ammonia mixed with a little muriat of iron.

ENS VENERIS. A preparation ſimilar to the foregoing, except that copper filings are ſubſtituted to thoſe of iron.

EPIDERMIS. See SKIN.

EPIDOT. See STRAHLSTEIN.

EPSOM SALT, See SULPHAT OF MAGNESIA.

ERBSENSTEIN. See LIMESTONE.

ERDOEL. See BITUMEN.

ESSAY. See ASSAY.

ESSENCE. See OIL *Eſſential.*

ESSENTIAL SALT. This term ſeems to be generally applied to expreſs any kind of ſalt procured from organized bodies, particularly vegetables, by ſimple extraction without any chemical decompoſition. It is therefore ſynonimous with *native* ſalt. Thus we have the *eſſential ſalt* of *ſorrel*, which is the native ſuper-oxalat of potaſh contained in the plant, and procured by expreſſion, clarification, and evaporation, all of them rather mechanical than chemical proceſſes. The ſupertartrite of potaſh is an eſſential ſalt in tamarinds, the citric acid in lemons, the malic acid in apples, and the like.

The medicinal virtue of plants was thought formerly to reſide peculiarly in the eſſential ſalt, ſo that a ſmall doſe of the latter would be equivalent to a proportionally large doſe of the plant itſelf, and hence the extraction of the eſſential ſalts was an object of more importance to pharmaceutical chemiſtry than it is at preſent eſteemed.

ETHER. *Ether*, Fr. *Aether, Naphte kunſtliche*, Germ.

Ether is a light, odorant, inflammable liquid, produced by the action of certain of the acids upon alcohol. Sulphuric ether being the beſt known we ſhall commence with this, and paſs ſucceſſively to the reſt of the ethers, reſerving for the concluſion of the article an examination of the various theories by which chemiſts have attempted to explain the rationale of this curious and intereſting proceſs.

* SULPHURIC ETHER.

The mode of preparing ſulphuric ether in ſmall quantities is as follows. Take a tubu-

lated glaſs retort of the capacity of five quarts or more, lengthen its beak by an adopter and paſs the other end of the adopter into a two necked quilled balloon receiver; fix another adopter into the oppoſite neck of the balloon, to which attach a common quilled receiver, placed in ſuch a poſition that the quill inſtead of pointing directly downwards as in the firſt balloon, ſhall ſlant gently upwards: then lute all the junctures with linſeed meal, except that of the retort to the adopter; adapt alſo an 18 ounce vial to the quill of the firſt receiver, and looſely cloſe the quill of the ſecond with a ſmall cork or a plug of wetted paper. The lute being moderately dry and hard, withdraw the retort and pour in through the tubular 32 ounces by weight of rectified alcohol, and a like quantity of concentrated ſulphuric acid. This latter, on account of its ſuperior ſpecific gravity, will fall immediately through the other liquid without producing much heat; in a ſhort time however a conſiderable quantity of heat is extricated and the two fluids are to be gradually mixed by communicating to them a gentle circular motion. When the mixture is compleat the retort is to be replaced in its former poſition, its juncture with the adopter is to be cloſed with lute, and a pot of lighted charcoal is to be placed beneath it. The firſt impreſſion of the fire drives over a little highly dephlegmated alcohol, but as ſoon as the mixture begins to boil, the ether itſelf paſſes over and condenſes on the ſides of the receiver in large ſtreaks: it is now eſſentially requiſite to keep the receiver as cool as poſſible by the application of wet cloths wrung out in cold water and frequently renewed, and if this is ſedulouſly attended to, by far the greater part of the ether will be condenſed in the firſt receiver, whence it will flow into the vial beneath, a little however will paſs through the ſecond adopter into the ſecond receiver, where it muſt be condenſed by the ſame means as have been already recommended for the firſt. The contents of the retort are to be kept moderately boiling till ſulphureous acid gas begins to paſs through the quill of the ſecond receiver, which may be known at once by its ſtrong ſuffocating odour: as ſoon as this is perceived the fire is to be withdrawn, and a minute or two after the vial is to be detached from the receiver, and its contents immediately poured into a ground ſtoppered bottle; being then replaced as before, the proceſs of diſtillation is to be recommenced till about four ounces more of a coloured liquid are produced, at which time the operation, as far as the procuring of ether is concerned, is finiſhed. The liquor laſt procured conſiſts of two diſtinct fluids in nearly equal proportions, of theſe the lighteſt is an impure ether called oil of wine, and the heavier is water mixed with a little ether, acetous and ſulphureous acids. The latter may be ſeparated from the former by inverting the vial that contains them, and holding its neck immerſed in water while the warm hand is applied to the upper part of the vial: the gentle warmth thus communicated is ſufficient to convert a little of the ether into vapour, and in conſequence to expel the acidulous liquor. The whole produce according to this mode of proceeding, from 32 ounces of alcohol and the ſame quantity of ſulphuric acid, is 14 ounces of impure ether condenſed in the firſt and ſecond receivers, and 2 ounces of oil of wine. By ſubſequent rectification in the manner hereafter deſcribed, theſe 16 ounces will afford 11 ounces of a very pure and highly rectified ether. Some chemiſts by way of ſaving trouble allow the ether and oil of wine to mix together in the receiver, and draw off exactly the ſame quantity of impure ether (18 ounces) as in the former method: this however is injudicious, ſince the quantity of rectified ether which it yields is by no means ſo great as when the latter and moſt impure part of the diſtillation is collected by itſelf. [a]

It appears from the experiments of Dollfuſs,[b] and is confirmed by the practice of thoſe who prepare ether in the large way, that ſulphuric acid is capable of converting into ether conſiderably more than its own weight of alcohol. The experiment of this able chemiſt to which we particularly refer is the following. Having mixed very ſlowly and gradually 32 ounces of ſulphuric acid, ſp. gr. 1.98, with an equal weight of alcohol, he diſtilled the whole by a very gentle fire. The firſt ten ounces that came over were dephlegmated alcohol combined with ſome ether, the anodyne liquor of Hoffman; the next portion amounting to twelve ounces was impure ether; after this were obtained two ounces more of impure ether contaminated by ſulphureous acid: the diſtillation was carried on ſtill further in order to dephlegmate the ſulphuric acid, till three ounces of a weak acidulous liquor mixed with a little thick oil were driven over. To the concentrated acid now remaining in the retort were added 24 ounces of alcohol, and the diſtillation was recommenced as before; the firſt ſeven ounces that were collected were anodyne liquor like the former, the next ten

[a] Leonhardi's Macquer, art Aether.

[b] Pharmaceutiſch-chemiſche erfahrungen.

ounces were impure ether, after which came two ounces more contaminated by sulphureous acid. The residual acid in the retort was again dephlegmated by driving over five ounces of acidulous liquor, and a third dose of alcohol amounting to twenty ounces was added; from this were obtained six ounces of anodyne liquor, 4 ounces of ether, one ounce of sulphureous ether, and four ounces of weak acidulous liquor with a little oil of wine. Lastly, twenty ounces more of alcohol were added and yielded 5 ounces of anodyne liquor, 8 ounces of ether, one ounce of sulphureous ether, and the residue being loaded with charcoal swelled up so much as to render its further concentration impossible. There were thus procured from 32 ounces of sulphuric acid and 96 ounces of alcohol, 28 ounces of anodyne liquor, 34 ounces of impure ether, and 6 ounces still further contaminated by sulphureous acid; the two last products, amounting to 40 ounces, yielded 28 ounces of highly rectified ether. The sulphuric acid remaining in the retort was quite thick and black in consequence of the charcoal deposited from the decomposition of the alcohol, but being filtered through pounded glass and afterwards rectified by distillation, afforded above 19 ounces of colourless sulphuric acid; sp. gr. 1.72.

Having thus ascertained that sulphuric acid was capable of etherizing a much larger proportion than its own weight of alcohol, it became a matter of some consequence to discover whether by adding the whole quantity of alcohol at once, an equal produce of ether could be obtained as when the process was divided into four distinct distillations. For this purpose M. Dollfus mixed at once 32 ounces of sulphuric acid of the same specific gravity as in the former experiment, with 96 ounces of alcohol, and proceeded to distillation. The first twelve ounces were alcohol but little altered, then came 34 ounces of impure ether, which by rectification afforded no more than about 11 ounces of pure ether: the succeeding products were weak acetous acid and sulphureous acid. The residue in the retort, by filtration and concentration yielded 27 ounces of sulphuric acid; sp. gr. 1.66.

From these experiments it appears that the following practical conclusions may be drawn. First, that by means of repeated distillations, one part of sulphuric acid will convert into ether from two to three times its weight of alcohol. Secondly, that the produce is the greatest when the distillation is carried on very slowly, and no doubt the quantity of ether would be very much increased if the anodyne liquor produced in one distillation was added to the alcohol employed in the succeeding one. Thirdly, that when the sulphuric acid becomes so thickened with the deposited charcoal as to be incapable of being further used, a large proportion of it may be recovered by filtration through coarse sand or pounded glass, and subsequent concentration.

Ether when fresh distilled is contaminated by sulphureous and acetous acids and a little coloured oil; in consequence of which it is necessary to have recourse to rectification in order to purify it. This is generally done by adding to the ether successive portions of caustic potash or soda dissolved in water, and shaking together the two fluids in a well closed bottle after each addition of alkali, till the odour of sulphureous acid is totally destroyed, the contents of the bottle are then to be poured into a retort, and on the application of a very gentle heat, never amounting to ebullition, the ether will pass into the receiver in a state of great purity, leaving behind it a watery saline liquor covered with a thin film of brownish yellow oil. When the ether is wanted for very delicate chemical experiments it may be again agitated with $\frac{1}{10}$ of its weight of alkaline ley, and distilled in a heat not exceeding 100° Fah. the first $\frac{3}{4}$ of the ether, being absolutely pure, is to be saved apart. [c] When ether is to be rectified with peculiar care, Scheele [d] recommends that the alkali employed for this purpose should be dissolved in alcohol instead of water: the advantage of this is that no spontaneous separation of the liquors takes place, and therefore the sulphureous and acetous acids are neutralized and separated with greater certainty. Distillation at a gentle heat will readily separate the ether from the other ingredients. A cheap and very effectual method of rectifying ether is the following, first employed by Mr. Woulfe: "Fill three-fourths of "a bottle with the impure ether, add a little "water and a portion of slacked lime. Agitate "the bottle with violence, and keep it for some "time in water before taking out the cork. If "the smell of the sulphureous acid be not re-"moved, add a little more lime and agitate a "second time. Decant off the ether into a "receiver and distil it over." [e]

Another very cheap and ingenious process was invented by Pelletier. [f] It consists merely in adding to the impure ether a little finely pulverized black oxyd of manganese: the mixture being

[a] Higgins's Minutes, p. 72. [b] Essays, p 301. [c] Thomson's Chemistry, ii. p. 229. [d] Memoires, i. p. 316.

corked up in a bottle or flask is to be well shaken together four or five times a day for the space of a week, at the end of which time the sulphureous acid, being first converted into the sulphuric by part of the oxygen of the manganese, is found combined with the metallic oxyd into sulphat of manganese, from which the ether may be poured off quite pure without the necessity of re-distillation. M. Dizé's method [g] is the same as the above, except that he separates the ether by distillation, which is probably an improvement.

Rectified sulphuric ether exhibits the following properties. It is a transparent colourless liquor, of a peculiar and to most persons an agreeably fragrant odour and a hot penetrating and somewhat suffocating taste. Its specific gravity, according to Lavoisier, is = 0.758. It is volatilizable more rapidly and at a lower temperature than any other liquid, a considerable proportion being lost, especially in warm weather, by merely pouring it from one vial into another: hence the vessels in which it is preserved ought to be very accurately closed, and for further security are often kept inverted in cold water. It boils at 98° under the usual atmospherical pressure, and at 20° *in vacuo*.

The elastic force of the vapour of ether whose boiling point at 29.75 bar. is 102° Fahr. has been examined by Mr. Dalton [h] with the following results. At 62° its force is equal to the pressure of 12.75 inches of Mercury; at 102° equal to 30 inches; at 147° equal to 64.75 inches; and at 212° equal to 137.67 inches.

Owing to the extraordinary rapidity with which ether evaporates, it possesses a very great power of refrigeration: this is made obvious to the feeling by pouring a little into the palm of the hand; it is almost instantly volatilized, and the hand becomes painfully cold. Another striking experiment to the same purpose is the following. Fasten a little fine tow by means of a thread round the naked bulb of a mercurial thermometer, and suspend it before the nozle of a double bellows, then pour some ether on the bulb so as to soak the tow thoroughly, and immediately direct upon it a continued stream of air from the bellows, renewing the ether as soon as it is evaporated: by this management at any common temperature of the atmosphere, the mercury in the thermometer will in about a minute be lowered to 0° Fah. Ether, notwithstanding its ready volatility, is capable of being congealed at a low temperature. If a small matrass full of this fluid is cooled down to — 25° Fah. by a mixture of snow and muriat of lime, and kept quiet in these circumstances for a few minutes, the liquor becomes gradually filled with brilliant transparent crystalline laminæ resembling benzoic acid or oxymuriat of potash, and presently, especially at a somewhat lower temperature, the whole is congealed into a white almost inodorous mass. [i] Ether is remarkably inflammable, taking fire instantly on the near approach of an ignited body: it burns with a large white flame and a little smoak, and is resolved into water, carbonic acid, and a minute quantity of charcoal. When passed through a red hot earthenware tube it is entirely decomposed, and a large production of carburetted hydrogen takes place. Ether remarkably increases the bulk of any of the permanent gases to which it is added, as was first observed by Dr. Priestley. [k] A small quantity of this fluid being mixed with oxygen confined over mercury, exactly doubled its bulk, nor could any additional portion occasion a further dilatation; nearly the same effect took place with atmospheric air, azot, hydrogen, nitrous gas, and carbonic acid, but by a slight agitation in water the ether was absorbed and the gas resumed its former dimensions unaltered in any of its properties. If oxygen gas thus dilated by ether is set fire to, it burns rapidly but does not explode, but if one part of this mixture is added to three parts of oxygen, an ignited body or the electric spark then produces a dreadful explosion, the products of which are water and $2\frac{1}{3}$ parts of carbonic acid gas. Hence it appears that one part of ether requires about 7, or more correctly 6.8 of oxygen for its saturation, the products being water with 4.6 carbonic acid, the proportion therefore of carbon to hydrogen in sulphuric ether is nearly as 5 to 1. [l]

Water and ether appear to combine with each other in two different proportions: if equal parts of these fluids are shaken together in a graduated tube, the ether will be found to have diminished in bulk about $\frac{1}{10}$, and the water to have enlarged in nearly the same proportion; the lower fluid consists of water saturated with ether, and the upper fluid is ether combined with a little water. The ether in this state is said to be *washed*, and acquires in consequence some properties that pure ether does not possess; in particular it is now capable of dissolving caoutchouc with great ease, whereas this substance is acted on by pure ether only in a very

[g] Thomson. [h] Manchester Phil. Transf. v p. 564. [i] Vauquelin. An. de Chim. xxix. p. 287.
[k] Experiments on Air, methodized, ii. p. 436. [l] Cruikshank in Nicholson's Journ. 4to. v. p. 205.

imperfect manner. Phosphorus is soluble in ether, but the solution is not luminous: when ether is boiled on phosphorus, it often deposits crystals by cooling;[m] agitation with water produces no apparent change in this liquid, but the addition of a little alcohol occasions an immediate turbidness, whence the sophistication of ether by alcohol may be detected by mixing a few drops of it with phosphorized ether.[n] The fixed alkalies seem to be incapable of uniting with ether, but ammoniacal gas is absorbed by it very copiously: the same may be observed of nitrous gas, but neither of these combinations have as yet been submitted to chemical examination. Sulphuric acid acts on ether with considerable energy, especially when assisted by a gentle heat; it is converted into a brownish oily fluid much heavier than ether, called *oil of wine*, and at a higher temperature is changed into olefiant gas. With regard to the action of oxymuriatic acid on ether a curious experiment is related by Mr. Cruikshank. "If we fill a bottle of the capacity of three or "four pints with the pure oxygenated muriatic "acid gas, taking care to expel the water as "completely as possible, and then throw into it "about a drachm or half a drachm of good ether, "covering its mouth immediately with a piece "of light wood or paper; in a few seconds "white vapour will be perceived moving cir-"cularly in the bottle, this will soon be fol-"lowed by an explosion accompanied by flame, "at the same time a very considerable quan-"tity of carbon will be deposited, and the bottle "will be found to contain carbonic acid gas." Nitric acid excites a considerable effervescence with ether, and seems to convert it into oil of wine. The essential oils are soluble in ether, and it combines with alcohol in almost all proportions.

** Nitrous Ether.

Although Nitrous ether appears to have been known to Basil Valentine and Kunckel, yet the mode of its preparation being kept a secret it soon ceased to be attended to by chemists, till in the year 1740 it was re-discovered by Duhamel, and afterwards more particularly described by Navier, Sebastiani, and others.

It was prepared by Navier in the following manner. Put 12 ounces of rectified alcohol into a strong bottle, and add to it gradually, and at intervals 8 ounces of strong nitric acid: after each portion of acid the liquors are to be well mixed by agitation, and the bottle is to be kept close corked and immersed up to its neck in ice and water. When the whole of the acid is added, the bottle is to be well corked and further secured by a leather cap. A stratum of ether rises by degrees to the surface of the liquor, and after five or six days the cork is to be pierced by a needle in order to let out the nitrous gas formed during the process: this gas having escaped the cork is to be drawn, and the whole contents of the bottle being poured into a separatory funnel, the ether is thus procured unmixed with the heavier fluid on which it floats. This is however a very rude way of proceeding, and is attended with the utmost risk to the apparatus, the ether obtained is also in small quantity and very impure. A safer and more economical, but somewhat tedious mode of proceeding was invented by Dr. Dehne.[o] He luted a tubulated retort to a large receiver, and poured into the retort 32 ounces of alcohol, to which he added every four hours half an ounce of fuming nitrous acid drop by drop. When twelve ounces and a half had been thus poured in, the mixture began to bubble but without much heat, and an ounce of ether came over into the receiver. After this two drachms of the acid only were added morning and evening: on the eighth day after the commencement of the process a stratum of greenish ether appeared on the surface of the liquor in the retort, which being removed on the twelfth day (at which period 21 ounces of acid had been added to the alcohol) was found to amount to 17 ounces. The daily addition of two drachms of acid was still continued till it fell to the bottom in the form of green bubbles, indicating the saturation of the alcohol; at this time eight ounces and three drachms more of ether were separated, amounting in the whole to 26 ounces and 3 drachms; the residuum weighed 28 ounces, and the loss of weight during the entire process amounted to 5 ounces.

In order to prevent the violent and rapid action of the concentrated acid on the alcohol, which is the chief difficulty in the preparation of nitrous ether, Dr. Black proposed to interpose a thin stratum of pure water, and Fischer on the same principle made use of a little weak spirit of nitre for a similar purpose. M. Dollfuss from a careful repetition of this latter process obtained the following result. Upon two ounces of strong nitric acid he poured six drachms of the same very much diluted, and upon this three ounces of rectified alcohol. The vial was loosely corked and suffered to stand undisturbed for three days: at this time

[m] Mrs. Fulhame on Combustion, p. 41. [n] Brugnatelli An. de Chim. xxiv. p. 73. [o] Crell's Chim. Journ. i. 44.

the lower liquor appeared perfectly homogeneous with a ſtratum of ether floating above it. The whole being put into a retort and ſubjected to a gentle heat, there was obtained two ounces and a drachm of very pure ether unmixed with any acid, and the reſidue in the retort conſiſted of weak acetous acid mixed with oxalic acid, nearly the whole of the nitrous acid having been decompoſed.

Another equally eligible method of preparing nitrous ether was invented by Chaptal, and has ſince in ſome reſpects been improved by Prouſt: It conſiſts in firſt putting together an apparatus conſiſting of a tubulated retort and two balloon receivers, each furniſhed with a tube of ſafety, and the whole terminated by three Woulfe bottles; 32 ounces of alcohol are then to be poured into the retort, and the Woulfe bottles are likewiſe to be half filled with alcohol: nitric acid is then to be poured by degrees into the retort till it amounts to 24 ounces; and then the tubulure being cloſed by its ſtopper a gentle heat is to be applied: both nitrous gas and ether are rapidly diſengaged, the latter of which is in part condenſed in the receivers, but principally in the Woulfe bottles where it floats on the ſurface of the alcohol. Dollfuſs[p] has repeated this proceſs in a ſimpler apparatus with the following reſults. Into a tubulated retort containing three ounces of alcohol he dropped one drachm of nitrous acid, repeating this at ſhort intervals till the quantity amounted to two ounces. Then diſtilling this mixture by a gentle fire he obtained two ounces and a drachm of ether: the reſiduum weighed two ounces, from which he procured by a ſecond diſtillation one ounce of a weak acetous acid: from the reſidue by the addition of a little more nitrous acid, there ſeparated by cryſtallization one drachm and 15 grains of oxalic acid.

The laſt mode by which nitrous ether may be prepared that we ſhall mention, and which on the whole appears to be the beſt, conſiſts in mixing together alcohol and ſulphuric acid, and pouring the liquor upon pulverized nitre; the ſulphuric acid diſengages the nitrous acid which immediately acts on the alcohol, and ether is the reſult. The able chemiſt whom we have already mentioned has ſhewn the excellence of this mode by the following experiment.[q] Having put into retort four ounces of perfectly dry and pulverized nitre, he added to it a mixture conſiſting of two ounces of concentrated ſulphuric acid, and four ounces of alcohol; the whole being ſubmitted to diſtillation there came over firſt ſix drachms of dulcified ſpirit of nitre, and then three ounces of a liquor, from which, by ſubſequent rectification were procured two ounces of pure ether.

Nitrous ether when recently made contains in looſe combination a conſiderable quantity of nitrous gas, which in ſome degree modifies its properties, and renders it particularly liable to burſt the bottles in which it is kept, eſpecially in warm weather; another inconvenience is, that if the bottles are not quite full and cloſed with perfect exactneſs, the nitrous gas by the abſorption of the oxygenous portion of the air is converted into nitrous acid, and in conſequence reacts on and deſtroys a part of the ether, converting it into water and oxalic acid, which in proportion as they are produced deſcend to the bottom of the veſſel forming an acid liquor on which the reſt of the ether floats. This loſs and trouble however may be avoided by rectifying the ether, which is done beſt in the following way. Pour into a ſtrong vial ſo as to fill it about two-thirds, one part of ether and four parts of pump water, and agitate it cautiouſly at firſt, and occaſionally removing the thumb from the mouth of the vial to afford a free paſſage for the diſengaged nitrous gas: when no more of this air is extricated, add a quantity of dry pearlaſh equal in weight to the ether, and ſhake the whole well together: then transfer the mixture into a tubulated retort and proceed to diſtillation, taking care that the temperature does not exceed 120° Fah.: the ether will paſs into the receiver quite pure, and may be kept for any length of time in ſtrong well cloſed bottles with no more riſk of accidents than ſulphuric ether is ſubject to.

Nitrous ether reſembles ſulphuric ether in moſt of its properties, it has however a dilute yellow colour, and a ſomewhat different odour and flavour; this appears to be owing to a little reſinous matter from which it can never be entirely freed: by repeated diſtillation from freſh parcels of dry white ſugar, as Deyeux has obſerved, this impurity may in great part be ſeparated, and in proportion as this takes place the ether becomes more and more analogous to that prepared by ſulphuric acid.

Nitrous ether appears capable of uniting with nitrous gas in two proportions: when the ether is in exceſs it forms nitrous ether in the ſtate in which it appears previous to rectification; when the nitrous gas exceeds the ether it compoſes a permanently elaſtic fluid that has obtained the name of *etherized nitrous gas*. The

[p] Erfahrungen, &c. [q] Do.

preparation of this differs from that of nitrous ether only in the rapidity with which the acid and alcohol act on each other: when the combination takes place very ſlowly much ether and little etherized gas is the reſult, but when the contrary is the caſe, theſe two products are formed in an inverſe proportion. If equal parts of alcohol and ſtrong nitrous acid are mixed together at the uſual atmoſpheric temperature, or at a higher heat in proportion as the acid is diluted, a very rapid and copious effervescence takes place, a little ether is condenſed in the receiver, and a large quantity of gas paſſes through the conducting tube, the firſt portions of which are etherized nitrous gas, and the latter part common nitrous gas. What remains in the retort is acetous acid with a little oxalic acid. The properties of etherized nitrous gas, according to Van Deiman and his aſſociates, to whom we are indebted for its diſcovery are the following.[r] It has a diſagreeable ethereous odour exactly reſembling that of oleſiant gas when treated with oxymuriatic acid. By the application of flame it takes fire and burns with a yellowiſh lambent flame like alcohol: after the combuſtion has ceaſed the veſſel in which it has been carried on contains a vapour of ſingular pungency. Water completely abſorbs this gas, but requires a conſiderable time to effect it except agitation is had recourſe to, reſembling in this reſpect carbonic acid. Alcohol produces the ſame effect as water, and takes up the gas not only more rapidly but alſo in larger proportion. A ſolution of cauſtic potaſh alſo diſſolves it, but with conſiderable difficulty, and on the addition of ſulphuric or muriatic acid the etherized gas is again ſet at liberty unaltered in any of its properties. Ammonia, whether liquid or in the gaſeous ſtate, is incapable of contracting any union with it. The ſame is the caſe with oxygen gas at the common temperature, but a mixture of the two airs when inflamed occaſions a moſt violent exploſion. Sulphuric acid inſtantly decompoſes this gas by abſorbing the ether, the nitrous gas retaining its elaſtic ſtate. Sulphureous acid produces the ſame effect, only it requires ſome days for this purpoſe. If ſulphuric acid previouſly diluted with an equal weight of water is placed in contact with this gas over mercury, its action is greatly retarded; the diminution of volume in the incloſed air takes place much more ſlowly, and even after ſome days a minute portion of etherized gas is retained by the nitrous gas, which in conſequence acquires the property of enlarging the flame of a taper that is immerſed in it, in the ſame manner as nitrous oxyd does. Nitrous acid according to its degree of concentration abſorbs either wholly or in part the ethereous portion of the gas; and the ſame may be obſerved of muriatic acid.

Etherized nitrous gas when paſſed through a red hot glaſs tube depoſits a little oil, and by ſubſequent waſhing with lime-water is freed from ſome carbonic acid; the reſidue is nitrous gas mixed or combined with common carburetted hydrogen, and is not acted on by ſulphuric, nitric or muriatic acids, by cauſtic potaſh or alcohol. The addition of oxygen gas produces red vapours, the nitrous gas is converted into acid, and the gaſeous reſidue is carburetted hydrogen.

*** Muriatic Ether.

After chemiſts had ſhewn the production of ether by means of the ſulphuric and nitric acids, it was natural to attempt its preparation by the muriatic acid. But this latter in its uſual ſtate of dilution with water has no action on alcohol, and therefore the various modes that were at firſt practiſed to produce muriatic ether entirely failed. A few chemiſts were ſaid to have ſucceeded by employing ſimple muriatic acid, but in a more concentrated and dry ſtate than the liquid acid; the proceſs however was both difficult and doubtful, and muriatic ether can hardly be ſaid to have been known till Rouelle diſcovered that it might be prepared by diſtilling together alcohol and the ſmoaking liquor of Libavius, which is a concentrated muriat of tin in its higheſt ſtate of oxydation. The Marquis de Courtanvaux having repeated the experiments of Rouelle with much care, propoſes the following as the beſt method of preparing the ſubſtance in queſtion. Mix together in a retort three parts of fuming muriat of tin and one of alcohol, a conſiderable degree of heat is immediately excited and a white ſuffocating vapour ariſes, which however ſoon diſappears on agitating the mixture. As ſoon as an ethereous odour is perceived, let two balloon receivers be luted on and kept as cool as poſſible, then by the application of a gentle heat to the retort there comes over firſt a little dephlegmated alcohol which is ſucceeded by the ether: by an increaſe of temperature a few drops of coloured oil are produced, and then ariſes partly in the form of a ſoft butter and partly in that of a denſe brown liquid, a quantity of ſmoaking muriat of tin, part of the metallic oxyd remaining in the retort as a grey powder. When the

[r] Jour. de Phyſ. xlv. p. 245.

ether thus procured is mixed with a ſolution of pearlaſh, a copious effervescence and precipitation takes place, owing to the decompoſition of ſome muriat of tin contained in the ether, after which by diſtillation at a gentle heat the muriatic ether ariſes in a ſtate of great purity amounting to half of the impure product of the firſt diſtillation.

Several other of the metallic muriats have been found to be equally efficacious with the liquor of Libavius: the corroſive muriats of antimony and arſenic, the muriats of biſmuth and zinc, and the red muriat of iron have in particular been uſed with ſucceſs in the preparation of muriatic ether.

Scheele, the diſcoverer of oxymuriatic acid, was induced to try the effect of this in the preparation of muriatic ether.[s] For this purpoſe he put three ounces of alcohol into a receiver, with which was connected a retort holding two ounces of common ſalt, upon which was poured an equal weight of ſulphuric acid; the muriatic acid thus diſengaged paſſed into the receiver where it combined with the alcohol, and this when ſaturated with acid was transferred to another retort containing three ounces of black oxyd of manganeſe in fine powder: the mixture inſtantly aſſumed a green colour and preſently after became ſo hot as to boil. When the ebullition had ceaſed there was found in the receiver a liquor from which on mixture with water a quantity of ether inſtantly ſeparated. The ſame method is recommended by Van Mons, except that he employs only one-fourth of the oxyd of manganeſe uſed by Scheele, and performs the ſecond diſtillation in a Woulfe's apparatus, the bottles of which contain a ſolution of cauſtic potaſh, by which the acid is prevented from reacting on the ether.

Another mode of applying oxymuriatic acid to the preparation of ether, firſt practiſed by Scheele, is mentioned by Pelletier,[t] and deſerves to be repeated as being perhaps the moſt expeditious and economical of any. He introduces into a large tubulated retort a mixture of eight ounces of manganeſe and 16 ounces of decrepitated muriat of ſoda, upon which he pours another mixture of twelve ounces of ſulphuric acid and eight ounces of alcohol. From this maſs ten ounces are drawn off by diſtillation at a gentle heat, which by ſubſequent rectification yields four ounces of ether.

It deſerves to be remarked that the ether prepared by oxymuriatic acid generally depoſits during its rectification with potaſh a conſiderable quantity of a clear aromatic and bitter oil, which ſinks in drops to the bottom of the veſſel: the ether alſo, according to Dollfuſs, at leaſt before rectification, is compleatly miſcible with water when ſhaken with it for ſome time.

The preparation of ether by means of ſimple muriatic acid is not eaſy, and was readily ſuppoſed to be impoſſible by ſome of the leaders of the modern ſchool of French chemiſts, becauſe it contradicted one of their early theories on the proceſs of etherification; yet Beaumé, a chemiſt of great experience and unqueſtioned veracity, had affirmed that he had obtained a ſmall quantity of ether by mixing together alcohol and muriatic acid both of them in the ſtate of vapour: La Planche alſo had obtained ether by adding to decrepitated muriat of ſoda a mixture of alcohol and ſulphuric acid, and diſtilling the whole by a gentle heat. A chemiſt of the name of Martin alſo affirms that he had prepared muriatic ether by cohobating equal parts of alcohol and muriatic acid, by which proceſs the quantity of ether obtained amounted to half of the alcohol employed. Finally the practicability of this method appears to be eſtabliſhed beyond doubt by the following formula of Mr. Baſſe.[u] Keep a quantity of common ſalt in fuſion for about an hour in order to drive off all the water of cryſtallization, then pulverize it and put 40 parts into a tubulated retort connected with a Woulfe's apparatus, the firſt bottle of which contains 20 parts of moſt highly rectified alcohol: then add to the ſalt in the retort 20 parts of the ſtrongeſt ſulphuric acid, and proceed to diſtillation by a gentle heat, keeping the alcohol-bottle as cool as poſſible. When the alcohol is ſaturated with acid, transfer it to a retort and diſtil over about one half of it; agitate this portion with an alkaline ley and the ether will preſently ſeparate and float on the ſurface, whence it may be obtained by decantation or diſtillation. The quantity of ether from the above materials amounts to 5 parts.

Muriatic ether has a ſtriking reſemblance to that prepared by ſulphuric acid; its ſpecific gravity however is greater, amounting according to Hermbſtadt to 0.84: its taſte alſo has a peculiar aſtringency like alum, and when burning it exhales a ſtrong acrid odour reſembling that of ſulphureous acid.

* * * Fluoric Ether.

All that we know of this ſubſtance is due to Scheele.[v] He firſt impregnated rectified alcohol

[s] Scheele's Eſſays, p. 302. [t] Memoires, i. p. 141.
[u] Van Mons Journ. de Chim. iv. p. 86. or Thomſon's Chim. ii. p. 246. [v] Eſs. p. 305.

with fluoric acid gas, by diſtilling pulverized fluor ſpar with ſulphuric acid and placing alcohol in the receiver: the ſmoaking ſpirit thus obtained was diſtilled with a gentle heat, but no ſign of ether made its appearance. Another portion of the acidulated ſpirit was then mixed with black oxyd of manganeſe, and by ſubſequent diſtillation an ethereous fluid came over, from which by rectification a little ether was obtained, of a very agreeable ſmell reſembling that of nitrous ether.

*** Acetic Ether.

Acetic ether was firſt diſcovered by the Count de Lauraguais; the method of its preparation was by diſtilling together equal parts of alcohol and acetic acid. Scheele, Bergman, Porner, and other chemiſts repeated this proceſs ineffectually, and hence were induced to ſuſpect ſome error. In conſequence of theſe doubts, Pelletier [v] entered into a careful examination of the ſubject, and has both ſhown the reaſon of the failure of Scheele, and has given the proper method by which to ſucceed. He diſtilled together equal parts of alcohol and acetic acid, and drew off a little more than half; this liquor was acidulous and had an ethereous ſmell, but no genuine ether could be made to ſeparate. He then mixed together 12 ounces of ſtrong radical vinegar and the ſame quantity of alcohol, and diſtilled over one half of it at a boiling temperature; this product he poured back into the retort and recommenced the diſtillation; the produce of this and of the third diſtillation were in like manner rectified, and having begun again for the fourth time he finally obtained 12 ounces of an ethereous fluid; with this he mixed a ſufficient quantity of carbonated potaſh to ſaturate the acid which it contained, and then ſubmitted it to a gentle diſtillation. The firſt ſix ounces that came over were pure acetous ether, the next four ounces alſo contained ether, but not ſo pure as the former. It is remarkable that during the cohobations a conſiderable abſorption of air took place.

Scheele obtained acetous ether in a more compendious manner by mixing together acetite of potaſh, or of lead (ſugar of lead), or of copper (diſtilled verdigris), with alcohol, and then adding as much ſulphuric acid as was requiſite to decompoſe the acetous ſalt and diſtilling the mixture at a low heat; the produce being ſhaken with water the ether riſes to the ſurface and may be poured off. From 16 parts ſugar of lead, 6 parts ſtrong ſulphuric acid, and 9 parts of alcohol, Bucholz obtained 6 parts rectified ether.

Acetic ether always retains the odour of the acid by which it is formed: it is not ſo volatile as the ethers procured by the mineral acids; it burns with a lambent blue flame like alcohol; it is ſoluble in a little more than twice its bulk of water, and is decompoſable into acetous acid by repeated diſtillations at a very gentle heat.

Various other acids have been diſtilled with alcohol for the purpoſe of procuring ether, but with little or no ſucceſs. Oxalic acid with an equal weight of alcohol yielded Bergman a watery ſomewhat etherized alcohol. Benzoic acid and alcohol, according to Scheele, afford no ether, but when a little common muriatic acid is added to the mixture, an ethereous liquor comes over, of which part floats on water and part ſinks in the ſame fluid. The ether, or the lighter portion, has the odour of benzoic acid, burns with a clear flame and ſmoak, and is about equal in volatility to acetic ether. The phoſphoric, boracic, tartareous, citric, and ſuccinic acids were found by the ſame able chemiſt to be incapable of producing ether either by their own action or alcohol, or when mixed with oxyd of manganeſe or muriatic acid.

**** Theory of Etherification.

Of the various theories by which chemiſts have endeavoured to explain the rationale of the curious and intereſting proceſs of etherification, we ſhall mention only three. The firſt of theſe, remarkable for its ingenuity and ſimplicity and the ſtriking ſimilarity which it bears to the theory of Vauquelin and Fourcroy in its leading principle, was invented by Macquer previous to the great changes introduced into the ſcience by the diſcoveries of Prieſtley and the other fathers of gaſſeous chemiſtry.

Spirit of wine, ſays Macquer, [x] which is at once inflammable and miſcible with water in all proportions, differs from any oil by containing a more conſiderable quantity of water, which enters into its compoſition as a principal or conſtituent part; hence if we deprive ſpirit of wine of that aqueous principle by which it differs from oils, it ought to approach ſo much the more to an oily nature in proportion as it is deprived of the water with which it is combined. Now this is preciſely what happens in the proceſs of etherification. When equal quantities of alcohol and ſulphuric acid are diſtilled together, the firſt produce is alcohol highly dephlegmated; then ſucceeds ether, which from

[v] Memoires, i. p. 238.

[x] Chem. Dict. art. Ether.

its burning with a white flame and fmoak, and being immifcible with water in all proportions, approaches nearer to the character of oil than alcohol does. When the alcohol has loft an additional quantity of water it is converted into oil of wine, which is a genuine oil, being not mifcible with water, burning with a fmoaky flame and leaving behind a refinous coal. In further confirmation of this it may be obferved that water is actually feparated from the alcohol during the whole of the diftillation. The objections to this repreſentation of the procefs independently of any theory are, that it notices and accounts for only a few of the changes that take place, and therefore is at beft imperfect: in particular the copious depofition of charcoal and the formation of acetous acid is wholly neglected.

When the theory and general deductions of Lavoifier began to be received among chemifts, and oxygen was confidered as the active principle by which all chemical changes were brought about, the formation of ether was very compendioufly explained in the following manner. The difengagement of fulphureous acid accompanies the production of ether, therefore "in "this operation the fulphuric acid is decom-"pofed, and its oxygen, by combining with the "hydrogen and carbon of the alcohol forms "three ftates, which we alfo find in the diftill-"ation of fome bitumens; 1. a very volatile "oil or ether; 2. ethereal oil; 3. bitumen." [y] Impreffed with this idea the fame chemift is led to the unfounded affertion that in all the modes of preparing muriatic ether, the acid is in the ftate of oxymuriatic acid. "It is evident there-"fore," adds he, "that ether is merely a com-"bination of alcohol with the oxygen of the "acids made ufe of;" and then in order to confirm this pofition he fays that ether may be obtained by repeated diftillations of alcohol from the red oxyd of mercury; an affertion which moft aſſuredly is falfe, except the mercurial oxyd was prepared by nitrous acid, and in conſequence of being inſufficiently heated contained a portion of it undecompofed; in which cafe it might perhaps form with alcohol a nitrous ether.

The laft theory which we fhall mention is that of Vauquelin and Fourcroy: it is the moft recent and, becaufe it is founded on a minute attention to the feveral phenomena that take place during the formation of ether, the moft fatisfactory of any that have yet been offered. The facts and obfervations by which this theory is fupported are the following. [z]

1. If one part of alcohol and two of fulphuric acid are mixed together, the temperature rifes to about 200° Fah. the mafs immediately acquires a deep brownifh-red colour, which deepens into black a few days after, and at the fame time exhales a vapour manifeftly ethereous.

2. Equal parts of concentrated fulphuric acid and rectified alcohol, acquire on mixture a temperature of 190° Fah.; bubbles of gas are extricated, the liquor becomes turbid and opaleſcent, and at the end of a few days acquires a deep red colour. The whole being then tranſferred to a diftillatory-pneumatic apparatus, and being heated to 207° Fah. ebullition takes place and ether paſſes over into the recipient: if the operation is carefully conducted, no elaftic fluid is difengaged, and the vapour when condenſed is found to be only water and ether. When the liquid thus obtained amounts to about half of the alcohol employed, fulphureous acid begins to be manifeft, and in a fhort time the production of ether ceaſes and is ſucceeded by oil of wine accompanied by water and acetous acid. The contents of the retort being kept boiling and becoming more and more concentrated as the diftillation proceeds, are conſtantly acquiring a higher temperature: when this amounts to about 234° Fahr. olefiant gas begins to come over and continues till the oil of wine ceaſes to flow. At this period carbonic acid gas firſt makes its appearance, the water and fulphureous acid gas ſtill continuing to be produced, and the reſidue in the retort conſiſts of little elſe than fulphuric acid thickened by charcoal. A longer continuance of the heat ſtill gradually increaſing produces a little water, which ſoon ceaſes, fulphureous acid, and carbonic acid, the laſt of which continues the longeſt: when no more gas is diſcharged, the reſidue in the retort conſiſts of ſulphur and charcoal.

Theſe are the facts, and from theſe the able chemiſts who obſerved them have concluded:

1. That the ſpontaneous action of alcohol and ſulphuric acid, when this laſt is conſiderably in exceſs, is ſufficient for the formation of ether without the aſſiſtance of any extraneous heat, and that by duly proportioning the two ſubſtances the alcohol might be wholly decompoſed and made to yield all the ether which it is capable of doing when treated in the uſual manner.

2. That the formation of ether is not owing to the affinity of the oxygen contained in the ſulphuric acid for the hydrogen or carbon of the alcohol, is manifeſt from the fact that in

[y] Chaptal's Elements of Chim. iii. p. 259. [z] An. de Chim. xxiii. p. 203.

the preparation of ether no ſulphureous acid gas is evolved till the production of ether has almoſt ceaſed. It muſt therefore be the entire attraction of the ſulphuric acid for one or more of the elements of the alcohol that determines its decompoſition; now ſince water is formed during the whole proceſs, and ſince the affinity of this for ſulphuric acid is known to be very powerful, it appears likely that this is the cauſe that deſtroys the equilibrium of the affinities by which the elementary particles of alcohol are retained in combination, and induces the oxygen and hydrogen to unite and produce water. Hence it might at firſt ſight be ſuppoſed that ether differs from alcohol in containing a ſmaller proportion of oxygen and hydrogen. This however will not be found to be the caſe when we advert to the depoſition of charcoal, which equally with the formation of water, accompanies the production of ether: now the amount of the charcoal depoſited, is greater, in proportion to that which is left, than the hydrogen of the water compared to what ſtill remains in the ether, therefore this latter fluid although compoſed of the ſame elements as alcohol, differs from it in containing a ſmaller proportion of carbon compared to the hydrogen. During the progreſs of diſtillation the heat to which the materials in the retort are expoſed is continually increaſing, and, the affinity of the acid and alcohol alſo augmenting, the acid itſelf is at length decompoſed: ſulphureous acid is generated, and the exceſs of oxygen deprives the alcohol of part of its hydrogen, whence reſults the oil of wine, differing from ether in containing a larger portion of carbon; and in confirmation of this it may be obſerved, that the carbon depoſited during the production of oil of wine is not ſo great as when ether is produced.

The authors of this hypotheſis having ſhown that during the formation of ether no decompoſition of the ſulphuric acid takes place, attribute to the acid only the power of detaining the alcohol in a heat more than ſufficient for the volatilization of this fluid when uncombined, and ſuppoſe that the production of ether and water and the depoſition of charcoal are to be wholly attributed to the action of caloric. Therefore ſay they, an analogous decompoſition of alcohol takes place in circumſtances reſembling in no reſpect thoſe in which ſulphuric ether is produced, except the expoſure of alcohol to an unuſually high temperature. Thus when perfectly cauſtic potaſh is mixed with dephlegmated alcohol and heat is gradually applied, the liquor becomes brown by the depoſition of charcoal, water is produced, and an odorant fluid paſſes over ſimilar in many reſpects to ether or oil of wine. So again, when the vapour of alcohol is paſſed through an earthenware tube almoſt red hot, a decompoſition takes place, the products of which are ſimilar to thoſe which appear in the formation of ſulphuric ether, except ſo far as theſe latter are modified by the decompoſition of ſulphuric acid. Charcoal is depoſited within the tube, a fragrant odour like that of ether is perceived, an oil which concretes into brilliant cryſtals like benzoic acid is produced, together with olefiant gas, carburetted hydrogen, and carbonic acid.

Such is the ſubſtance of this very ingenious theory, and ſuch are the facts by which it is ſupported; upon which we ſhall make a few remarks.

In the firſt place it would have been more ſatisfactory if the gas had been examined, which we are told is diſengaged when equal parts of alcohol and ſulphuric acid are mixed together. Secondly, the acetous acid which is copiouſly formed as long as the oil of wine continues to flow is entirely neglected. Thirdly, the relative proportions of charcoal in alcohol and ether are contradictory to ſome apparently correct analyſes of theſe ſubſtances by chemiſts of acknowledged ability. Lavoiſier from the reſult of his experiments on fermentation, makes the relative proportions of hydrogen and carbon in alcohol to be as 1 to 1.7: but the proceſs of fermentation is ſo complicated, that no great dependence can be placed on this reſult. Let us therefore have recourſe to a ſimpler, and on that account more ſatisfactory analyſis of the ſame fluid by the ſame chemiſt. From the combuſtion of alcohol in oxygen gas, Lavoiſier found the proportions of hydrogen and carbon to be : 1 : 3.6. In ether the proportions of hydrogen and carbon according to Cruikſhank, are : 1 : 5. Oil of wine has not been analyſed; but in olefiant gas according to Henry, the hydrogen and carbon are : 1 : 5.7 at leaſt, and probably the carbon is in a conſiderably higher ratio. Now, ſince during the decompoſition of alcohol when diſtilled with ſulphuric acid, ether, oil of wine, and olefiant gas make their appearance in ſucceſſion; ſince water is produced during the whole proceſs, and ſince the depoſition of charcoal alſo takes place but in a diminiſhing ratio, it appears probable that theſe different ſubſtances form part of a regular ſeries, of which alcohol is one extremity, and olefiant gas the other, and in which the proportion of carbon is conſtantly increaſing, and that of the hydrogen and oxy-

gen diminiſhing; but as theſe two laſt are ſeparated in conſequence of the production of water, and perhaps of acetous acid, the oxygen muſt be abſtracted in much greater proportion than the hydrogen, ſo that the ultimate reſult of this method of decompoſition will be carburetted-hydrogen, the oxygen being entirely expended.

Perhaps the following modifications of the theory of Vauquelin may in ſome degree add to its conſiſtency. Alcohol and ſulphuric acid in equal proportions being expoſed to a conſtantly increaſing temperature, the acid ſeparates the water contained in the alcohol, and in conſequence highly dephlegmated alcohol is the earlieſt product of the diſtillation: a greater degree of heat, added to the affinity of the acid for water, decompoſes part of the alcohol; its oxygen and hydrogen produce water, and carbon is depoſited; but theſe its elements being ſeparated in unequal proportions ether is the reſult. At a ſomewhat higher temperature, before the ether has ceaſed to flow, the carbon and hydrogen as they are ſeparating from the alcohol react on the ſulphuric acid, take away a portion of its oxygen and form acetous acid, while ſulphureous acid gas is volatilized together with the laſt portions of ether. A ſtill greater heat takes away from the alcohol a larger proportion of its oxygen and hydrogen, and oil of wine is the conſequence; which probably differs from ether, in containing more carbon and leſs oxygen; the production of water, acetous acid, and ſulphureous acid proceeding as before. The temperature ſtill going on to increaſe, the oil of wine is itſelf partly decompoſed, and olefiant gas is thus added to the products of the diſtillation. The oil of wine, olefiant gas and acetous acid at length ceaſe, and nothing comes over but a little water, ſulphureous acid and carbonic acid, theſe laſt being no doubt produced by the action of the charcoal on the ſulphuric acid.

Hence the whole proceſs of etherification, comprehending the converſion of alcohol into ether, oil of wine and olefiant gas may be conſidered as the effect of a conſtantly increaſing temperature, the action of which the alcohol is prevented from eſcaping in conſequence of its affinity for the ſulphuric acid (and as a further proof of this affinity it may be remarked that the moſt accurately rectified ether always contains a notable quantity of ſulphuric acid) The decompoſition of this acid and conſequent production of ſulphureous acid gas has nothing to do with the proceſs of etherification; it being cauſed in the firſt part of the operation by the formation of acetous acid, and in the latter part of it by the formation of carbonic acid.

It will now be proper to take notice of ſome objections that have been urged againſt the theory of Vauquelin and Fourcroy, founded upon experiments in which oxyd of manganeſe was employed, together with the uſual materials of ſulphuric ether, and which are ſuppoſed by many to demonſtrate the neceſſity of oxygen in the converſion of alcohol into ether.

It was Scheele who firſt remarked, that if black oxyd of manganeſe be mixed with ſulphuric acid and alcohol, and the whole ſubjected to diſtillation, ether is produced without any ſulphureous acid making its appearance. This experiment was repeated by Dabit [z] with ſucceſs, and is urged by him to ſhow the neceſſary agency of oxygen in the formation of ſulphuric ether. The acid and the manganeſe immediately react on each other, ſays he, ſulphat of manganeſe is the reſult, and oxygen is diſengaged; but no oxygen gas is produced during the whole of the diſtillation, therefore the oxygen muſt combine with the alcohol to form ether. Further, there is no depoſition of charcoal in the retort, therefore none of the alcohol is deſtroyed as in the common mode of proceeding. Vauquelin however has poſitively ſhown, that in the diſtillation of ſulphuric acid and alcohol the greateſt part of the ether paſſes over before any ſulphureous acid is produced; and in reply to this M. Dabit has only to urge the unproved aſſertion that ſulphuric acid may loſe a part of its oxygen without becoming ſulphureous acid. Theſe objections induced M. Vauquelin to repeat with care the experiments of Dabit, the reſult of which was a complete refutation of his theory.

[a] Equal parts of ſulphuric acid, alcohol, and oxyd of manganeſe were mixed together and immediately ſubjected to diſtillation: a liquor was obtained amounting to about half of the alcohol employed, which had ſomewhat of an ethereous odour, but was of a bitter and very diſagreeable flavour, was entirely miſcible with water, and was ſpecifically heavier than the alcohol made uſe of, this latter being $= 0.83$, and the former $= 0.86$. This liquor being rediſtilled with carbonated alkali, and $\frac{4}{5}$ of it being drawn off, was found to have acquired a more ethereous odour, its ſpecific gravity was $= 0.82$; when mingled with an equal bulk of water, be-

[z] An. de Chim. xxxiv. 294. [a] D° p. 320

tween $\frac{1}{3}$ and $\frac{1}{4}$ of it remained undiſſolved in this fluid, and this undiſſolved part was extremely analogous to common ſulphuric ether. On examining the reſidue of the firſt diſtillation a quantity of charcoal was found depoſited, and this being contrary to what M. Dabit had affirmed, it was ſuſpected by M. Vauquelin that in conſequence of proceeding to diſtillation immediately after the mixture of the materials, part of the ſulphuric acid inſtead of combining with the oxyd of manganeſe had acted immediately on the alcohol, and thus had cauſed the depoſition of charcoal and had generated a little real ether. In conſequence of this ſuſpicion a ſecond mixture was made of equal parts of ſulphuric acid, manganeſe and alcohol, and was allowed to ſtand 48 hours before it was diſtilled. The product of the diſtillation was a liquid equal to $\frac{6}{10}$ of the alcohol, the odour and nauſeous flavour of which were very different from ether. Being rectified in the uſual way, ſomewhat more than half of the liquor was drawn off, which exhibited the following properties. Its ſpecific gravity was $= 0.85$, greater than that of the alcohol; it was miſcible with water in all proportions; it was leſs volatile than ether, and its flame though white and accompanied by ſmoak conſiderably reſembled that of alcohol. On examination of the reſidue of the firſt diſtillation no charcoal was found to be depoſited, and this ether when analyſed by paſſing through a red hot earthenware tube, appeared to contain a larger proportion of oxygen and carbon than true ſulphuric ether. The facts therefore which have been urged by M. Dabit againſt the theory of Vauquelin, are in reality a ſtriking confirmation of it, and are particularly intereſting as demonſtrating the exiſtence of an intermediate ſubſtance between alcohol and ether.

The phenomena that take place during the formation of nitrous ether are too complicated, and have been too little obſerved with the requiſite attention to allow us to lay down a ſatisfactory theory on the ſubject: not only the alcohol but even the acid is decompoſed from the very moment of their mixture; nitrous gas is extricated, and therefore part of the oxygen of the acid is combined with the alcohol; it muſt be obſerved however that no charcoal is depoſited, and that oxalic and acetous acids are formed beſides water and ether; it is very poſſible therefore that here, as in ſulphuric ether, the water and ether are produced by a new arrangement of the elements of the alcohol, and all the oxygen contributed by the acid is employed in the production of the oxalic and acetous acids.

Where ether is made from the action of muriatic acid on alcohol, it is obvious, as the acid is not decompoſed in any part of the proceſs, that this is not in any degree brought about by the action of oxygen. Even when the concentrated metallic muriats are uſed inſtead of the ſimple acid, it may be queſtioned whether the whole effect is not to be attributed to the concentration of the acid and the remarkable affinity which theſe ſalts have for water. The acid in theſe ſalts is certainly not in the ſtate of oxymuriatic acid, and it appears from Prouſt[b] that when the ſmoaking muriat of tin is made uſe of for this purpoſe, the metallic oxyd is in preciſely the ſame ſtate of oxydation after as before it has been employed in the preparation of ether. The only fact in oppoſition to this is noticed by Scheele, namely, that the green muriat of iron is incapable of converting alcohol into muriatic ether, whereas the red muriat will effect this change with great eaſe. He has however omitted to mention whether the red muriat is found after the proceſs in the ſtate of green muriat, which would be the caſe if the former ſalt acted in conſequence of its exceſs of oxygen. Muriatic acid, alcohol, and oxyd of manganeſe however will produce ether, and the oxymuriatic acid is at the ſame time converted into ſimple muriatic acid: but according to Mr. Baſſe,[c] the liquid thus produced is not an ether but very ſimilar to the ethereal liquor of M. Dabit mentioned above, and if this is a correct repreſentation, this objection alſo falls to the ground.

It is an enquiry which has been agitated among chemiſts whether all the ethers are eſſentially and radically the ſame; and it may be ſuppoſed that if the theory of etherification is the ſame in all, the product reſulting from this identity of action ſhould alſo be the ſame whatever acid is made uſe of: but in oppoſition to this it may be ſtated on the authority of Scheele, that every ether combines with and retains, even after rectification with alkali, a portion of the acid, by the agency of which it was formed, and therefore that there is a real ſpecific difference between ethers depending on the particular acid which enters into their compoſition.

ETHIOPS.

This term is at preſent obſolete: it was uſed by the old chemiſts to denote four different

[b] An. de Chim. xlii. p. 271.

[c] Journ. de Chim. iv. p. 88.

metallic preparations of a dark colour, which were for the moſt part employed in pharmacy.

1. ETHIOPS ANTIMONIALIS.

This is a double ſulphuret of antimony and mercury, and is prepared either by triturating equal weights of crude antimony and mercury, till the mercury is no longer fluid; or by fuſing ſome ſulphuret of antimony in an earthen crucible, and when it is upon the point of fixing, to pour in an equal weight of hot mercury; the mixture immediately becomes fluid, and after a while ſolidifies: when cold it muſt be levigated in a mortar and waſhed. Inſtead of crude antimony the golden ſulphur of this metal is ſometimes made uſe of.

ETHIOPS MARTIALIS.

This is the pure black magnetic oxyd of IRON; which ſee.

ETHIOPS MERCURII *per ſe*.

By this name the older German pharmacopœias diſtinguiſh an imperfect oxyd of MERCURY, made by triturating this metal with gum arabic or any other ſimple mucilage: it is an extremely inartificial and imperfect preparation, the mercury being for the moſt part not oxydated, but only reduced to a ſtate of very minute diviſion.

ETHIOPS MINERALIS.

This is the artificial black ſulphuret of MERCURY; which ſee.

EUCLASE. *Hauy*.

The colour of this mineral is a very clear ſea-green. It occurs only cryſtallized. Its primitive form is that of an oblique quadrilateral priſm, but its ſummits are generally ſo complicated by truncatures and bevillings as to render a mere verbal deſcription of it entirely unintelligible: in this ſtate it reſembles certain varieties of Topaz, but may readily be diſtinguiſhed by the meaſurement of the obtuſe angles of the priſm being 133° inſtead of 124°, and in its lamellæ not being perpendicular to the axis of the cryſtal. It has a brilliant vitreous luſtre. Its fracture in the direction of its axis, and parallel to the ſmall diagonal of its baſe, is perfectly lamellar, but when parallel to the large diagonal is very imperfectly ſo. Its croſs fracture is ſomewhat conchoidal. It is tranſparent and has a double refraction. It is ſufficiently hard to ſcratch quartz, but is remarkably brittle. Sp. gr. = 3.06.

When expoſed to the blowpipe this mineral firſt loſes its tranſparency, and then melts into a white enamel. It has been analyſed by Vauquelin, with the following reſult.

Silex . . .	35 to 36
Alumine .	18 — 19
Glycine . .	14 — 15
Iron . . .	2 — 3
	69 — 73
Loſs . . .	31 — 27
	100 100

This mineral is ſo very rare that only a ſmall portion could be afforded for analyſis: of the loſs, Vauquelin attributes the greateſt part to water of cryſtallization, and the reſt is probably alkali.

The Euclaſe was found in Peru by Dombey, and all the ſpecimens in the cabinets of Europe were brought over by this naturaliſt.

EUDIOMETRY.

The term eudiometry is applied to thoſe proceſſes that have been employed to aſcertain the purity, or in other words the degree of oxygenation of any gaſeous mixture, and eſpecially of atmoſpherical air.

The relative fitneſs of air for the purpoſe of reſpiration and combuſtion is certainly a queſtion of high importance, and it has been an object of great moment to determine how far the circumſtances of climate, expoſure, prevailing wind, and all other meteoric phenomena, crouded population, perceptible fumes or ſuppoſed noxious vapours of different kinds, and other cauſes that affect the ſenſible quality of the atmoſphere, really alter its chemical compoſition. Beſides the varieties in the natural atmoſphere, chemiſts alſo are conſtantly producing different gaſeous mixtures, the analyſis of which is deſired; and as far as relates to the quantity of oxygen contained, eudiometry here alſo may be put into practice: but by far the greater number of eudiometrical obſervations and experiments that have been made relate to the conſtitution of the atmoſphere alone under different circumſtances.

The preciſe conſtitution of *atmoſpherical air* is deſcribed under that article; it may be conſidered as a chemical mixture of azotic and oxygen gaſſes (the ſmall portion of carbonic acid being ſet aſide) in the average proportions of 78 of the firſt and 22 of the ſecond, eſtimating by bulk, or of 74 to 26 by weight.

All the eudiometric proceſſes have only for their object to aſcertain directly the quantity of oxygen, and the only methods commonly employed are the oxygenation of nitrous gas, of a hydro ſulphuret, of hydrogen, and of phoſphorus, each of which require a ſeparate con-

ſideration. The ſubject of eudiometry, being one in which much accuracy is required, was long ſurrounded with difficulties; very complicated chemical decompoſitions have been diſcovered in proceſſes that at firſt were conſidered only as inſtances of ſimple oxygenation; all the ſcrupulous minuteneſs in manipulation, and in eſtimating the real quantities of gaſeous bodies has been found eſſential to procuring juſt and accurate reſults; and hence it has happened that none of the diſcoverers of theſe proceſſes have been the perſons to bring them to perfection. We ſhall therefore in this place only enlarge upon the latter experiments. The concurring teſtimony of all the accurate eudiometers ſhews ſo great, and to moſt philoſophers unexpected, a ſimilarity in the conſtitution of the atmoſphere in almoſt every ſituation in which man can be placed, and in every change of climate or weather, that when we find ſuch enormous differences in the degree of oxygenation of the atmoſphere as ſome obſervers have given, we may fairly doubt the fidelity of the experiments, or the competency of the method employed. In general therefore we can find no ſurer teſt of the accuracy of any eudiometrical proceſs than that, with the ſame manipulations it will always ſhew nearly the ſame quantity in the atmoſphere at all times and ſeaſons, that is, within the limits of about one per cent. over or under an average. Inſtead of this we find on the average of the reſults of different experimenters a range of ſometimes 8 or 10 per cent. in the ſtatements of the quantities of oxygen, even where the ſame eudiometric ſubſtance has been employed; a circumſtance which ſhews the neceſſity of uniformity not only in the general mode, but even in very minute particulars in order to give comparable reſults between the obſervations of different chemiſts.

Of nitrous gas as an eudiometer.

This was the firſt eudiometer employed, being uſed by Dr. Prieſtley in his original experiments immediately connected with his great diſcovery of oxygen gas. If nitrous gas be mixed in a glaſs jar over water with *oxygen* (both ſuppoſed to be perfectly pure and in the proportions in which they mutually ſaturate each other to form nitric acid) there will be a total diſappearance of both gaſſes, the water will be ſeen to riſe and fill the jar, entirely abſorbing the newly formed nitric acid in its paſſage. Though this total abſorption of the two gaſſes never actually takes place, yet when they are as pure as poſſible, and in accurate proportions, it is ſo nearly complete that the reſidue amounts only to a very minute quantity, and is found by experiments to be azotic gas. On the other hand, when nitrous gas is added to *atmoſpheric air*, or any other mixture of azot and oxygen, a certain and conſiderable abſorption takes place and in direct proportion to the quantity of oxygen preſent, ſo that, ſuppoſing a conſtant uniformity of action to be exerted, nitrous gas would poſſeſs all the requiſites for a perfect eudiometer. Thus, for example, if one meaſure of pure nitrous gas be added to the ſame quantity of common air, after a complete mixture of the two has been effected, the airs will only occupy the ſpace, on an average, of about 1.08 inſtead of 2. and conſequently .92 parts will have been abſorbed. This reſult Dr. Prieſtley was in the habit of denoting by the expreſſion, that the air was of the purity of 1.08, equal parts of the two gaſſes being always uſed. This proportion of nitrous gas is indeed more than ſufficient to ſaturate the oxygen of the atmoſpherical air, but as no error can ariſe from an exceſs of nitrous gas equal to that of having a deficiency of it, theſe proportions are generally uſed for all airs ſuppoſed to contain not much more oxygen than the atmoſphere. For giving *comparative* reſults of the oxygenation of airs, therefore, no further calculations would be requiſite, could the purity of the nitrous gas be enſured. But as the expreſſion, an air of the purity of 1.08, only implies that 1.08 is the unabſorbed reſidue when 1. of nitrous gas is mixed with 1. of common air, or in other words, an abſorption of .92 parts, the actual quantity of oxygen contained in the air muſt be ſought for by other data, which ſhall determine the relative proportions in which nitrous air and oxygen muſt be combined to produce a total abſorption, and form nitrous acid. Thus if it is found that 3 parts of nitrous gas are required fully to ſaturate and convert into nitrous acid 1 part of oxygen gas, the .92 parts abſorbed in the former inſtance will have been produced by the union of .69 of nitrous gas and .23 of oxygen; and as all the oxygen is removed from the air by this treatment (there being much more than ſufficient nitrous gas for the purpoſe) we may thence infer that 100 parts of the atmoſpherical air examined contains 23 of oxygen.

The eudiometer by nitrous gas therefore requires, for actual reſults, the ſupport of another eſſential experiment, in which reſpect the chance of error is greater than if the oxygen was removed by a ſolid or a liquid put in contact with the air to be examined, and where all

the reſidue might be ſimply that of the unabſorbed portion of this air alone. This difference however in the mode of eſtimation would be of no importance could the action of nitrous gas be brought to be uniform under all circumſtances, and diveſted of many anomalies and uncertainties that now attend its uſe. The chief of theſe are the following:

By the very ingenious and accurate experiments of Fontana, Ingenhouz, and Cavendiſh, it has been fully ſhewn that different portions of the very ſame gaſſes will undergo an enormous difference of abſorption according to the width of the tube in which they are mixed, the time of ſtanding together, the mode of ſhaking, and other ſmaller manipulations. Thus, as Mr. Cavendiſh has obſerved [e], if 1 meaſure of nitrous gas, and as much common air be rapidly mixed and immediately ſhaken, the abſorption will be nearly half the mixture, but if the airs are ſuffered to remain in contact about a fourth of a minute before they are ſhaken, the abſorption will be no more than about .8. The nature of the water too in which the experiment is made is found moſt materially to influence the reſult. Theſe differences might however be avoided, and the experiments made in this way might be univerſally comparable if chemiſts would agree to adopt the ſame preciſe method of operating in all the minute particulars that are found to affect their accuracy.

Thus Mr. Cavendiſh, by obſerving theſe precautions, was enabled to aſcertain the very great uniformity of the compoſition of common air in different ſeaſons and ſituations.

The actual quantity of oxygen contained in the air examined is found (as above-mentioned) by the known compoſition of nitric acid; there is however another method, which is the removal of unſaturated nitrous gas from the reſidue which contains only this gas and azot, and thus leaving the azot belonging to the air examined. For this purpoſe however it is eſſential to enter into a minute inveſtigation of the nature of the nitrous gas employed, and to aſcertain what are its impurities, and whether it can contain any azot, which, by mixing with the azot of the common air, might occaſion an error in the inference drawn from the quantity of unabſorbed reſidue.

The very elaborate ſeries of experiments on this ſubject undertaken by Humboldt [f] firſt, and afterwards by this chemiſt and Vauquelin [g], require ſome attention in this place, though all the obſervations contained therein have not been confirmed by other enquirers, and though ſome of the calculations are founded on hypothetical data, and imply a minuteneſs of inveſtigation on which the known uncertainty of theſe experiments will not allow us to place implicit confidence.

According to the above-mentioned chemiſts, when nitric acid of any ſtrength is added to copper wire (which is the uſual method of procuring nitrous gas) an effervеſcence more or leſs vehement takes place, and a gas is diſengaged conſiſting of nitrous gas, but always mixed with a portion of azot. The quantity of the latter is found to vary extremely according to the ſtrength of the acid, being from about one-tenth to nearly half the entire gas. Hence the neceſſity of finding that degree of ſtrength of the acid which will produce the pureſt nitrous gas: and this degree Mr. Humboldt ſtates to be, that in which the ſpecific gravity is about 1.15 to 1.17, or from 17 to 21 of Beaume's areometer. An acid either ſtronger or weaker than this gives a much more impure gas.

The mixture of azot with the nitrous gas the above chemiſts aſcertain in two ways, by ſulphat of iron and by oxymuriatic gas. Dr. Prieſtley had found [h] that when nitrous gas was agitated with a ſolution of ſulphat of iron, a large portion of the gas was abſorbed and the ſolution became thereby of a dark reddiſh black colour, and acquired an acid taſte, whilſt the unabſorbed reſidue was pure phlogiſticated (azotic) air, or nearly ſo, as one meaſure of it with as much of freſh nitrous air occupied the ſpace of 1.92 meaſures. Hence if the reſidue be the azot preexiſting in the nitrous gas, and not formed by the action of the ſulphat of iron, this appears a ſimple and ready way of aſcertaining the purity of the nitrous gas, and removing it from the azot left in theſe eudiometrical experiments.

The preciſe nature of this mutual action of nitrous gas and ſulphat of iron was examined by Meſſrs. Humboldt and Vauquelin in the following way: to a ſolution of 1½ ounce of ſulphat of iron 252 cubic inches of nitrous gas were thrown up, of which 180 were ſpeedily abſorbed. The ſame gas had been previouſly tried with the ſame teſt, and the whole was abſorbed except a reſidue of 12 per cent. which was azot. This ſolution of iron then ſhewed the following appearances: 1ſt, with potaſh, a deep green oxyd of iron was ſeparated, and a very ſenſible *ammoniacal* ſmell was given out: 2d, with ſulphuric acid, white vapours were expelled, which were found to be nitrous acid:

[e] Phil. Tranſ. vol. 73. [f] An. Chim. tom. 28. p. 123. [g] D° D° p. 181. [h] Expts. on Air, vol. 2. p. 13.

3d, tincture of litmus was ſtrongly reddened by the ſolution, though the nitrous gas had paſſed through potaſh in its way to the ſolution of iron. From theſe trials the preſence of an acid in exceſs, of nitric acid, and of ammonia were detected, and conſequently ſome change muſt have taken place capable of converting the nitrous gas into nitrous acid, and of uniting azot and hydrogen (the conſtituents of ammonia) in ſuch a manner as to produce this alkali from materials which gave no indication of it before mixture. For further certainty the ſolution was put into a retort, ſuperſaturated with potaſh, and diſtilled gradually nearly to dryneſs. The diſtilled liquor had an ammoniacal ſmell and gave white fumes when a piece of glaſs moiſtened with muriatic acid approached it, and being afterwards ſaturated with this acid and diſtilled to dryneſs, 4 grains of pure muriated ammonia were collected. The firſt reſidue (or that of the ſulphat of iron with nitrous gas and potaſh nearly dry) was then waſhed with pure water, which by ſubſequent evaporation gave 17 grains of nitre.

To compleat the experiment, the gas that had eſcaped the firſt action of the iron ſolution, amounting to 72 cubic inches, was agitated with ſulphat of iron and a large portion was abſorbed. If it had contained the whole of the azot of the 252 inches of nitrous gas (amounting at 12 per cent. to 30.24) only 42 inches would have been abſorbed, but inſtead of this the whole diſappeared except 8.64 inches of azot. Hence it follows that the difference between 8.64 and 30.24, or about 21 inches of azotic gas had alſo been abſorbed by the iron ſolution as well as the nitrous gas. It is to this abſorption of azot that the authors of this experiment chiefly look for the explanation of the preſence of the ammonia in the ſolution. Both nitric acid and ammonia are allowed to be formed in the experiment, the nitrous gas, ſay they, gains the oxygen neceſſary to complete its acidification by decompoſing part of the water preſent. The hydrogen of the decompoſed water then unites to the diſengaged azot (preſent in the proportion of 12 per cent. of the entire gas) and forms ammonia, and again the nitrat of ammonia decompoſes by double affinity an equivalent portion of ſulphat of iron, ſo that the ſolution contains nitrat of iron, ſulphat of ammonia, and ſulphat of iron, and the reſidual gas is ſimply that portion of the azotic impurity of the nitrous gas which has eſcaped the complicated action of theſe affinities.

M. Humboldt then endeavours to confirm this hypotheſis of the preſence of azot in nitrous gas being accidental and preexiſtent in the gas before the action of the iron ſolution (on which the whole of his eudiometric ſyſtem is founded) by analyzing the ſame nitrous gas by oxymuriatic acid gas. By this reagent (allowing for corrections in the eſtimate on account of the impurity of the acid gas and of the water whereby the two gaſſes are mixed) Mr. H. finds a larger reſidue of azot than when ſulphat of iron is uſed to decompoſe the nitrous gas. Now the oxymuriatic acid will certainly abſorb and oxygenate the nitrous gas, but, as the author of the experiment ſuppoſes, it will not act in any way upon any portion of azot that may be mixed with it as in the former caſe, nor will there be any ammonia formed in this inſtance, the preſence of this alkali being abſolutely incompatible with this acid. Hence the increaſe in the quantity of reſidual azot is ſuppoſed to be owing to the addition of that portion which, when the ſulphat of iron was uſed, went to form ammonia, and which therefore may be now eſtimated. Thus, in the actual numbers of a given experiment (with the corrections that the reader may be aware of the difficulties that oppoſe a very accurate reſult) 100 parts of nitrous gas mixed with as much oxymuriatic acid gas left a reſidue of 20 parts of azot. The acid gas was previouſly found to be abſorbed by water all but 10 per cent. of air nearly atmoſpherical, of which 4 parts were found to be oxygen and 6 azot; and conſequently theſe 6 parts of azot muſt be deducted from the reſidue of 20, leaving 14 for the whole of the azot preexiſting in the nitrous gas. On the other hand, 100 parts of the ſame nitrous gas analyzed by ſulphat of iron left 11 parts of azot. Of this number 2 are to be deducted for the azot of the interſtitial air of the ſolution, and the remaining 9 parts are the quantity of preexiſtent azot in the 100 parts of nitrous gas as indicated by the latter mode of analyſis. Conſequently the difference in the quantity of azot indicated by the two modes of analyſis, that is between 14 and 9, or 5 parts, are ſuppoſed to be the azot entering into the compoſition of the ammonia which is formed only in the firſt inſtance.

Humboldt has ſhewn very ſatisfactorily that the eudiometrical mixture of nitrous gas and atmoſpheric or oxygen gas cannot be made to anſwer when performed over mercury, which were it practicable would be highly to be wiſhed on account of the complication in the experiment cauſed by the action of water alone on

nitrous gas, and alſo of the air contained in all common waters. But when the mixture is made over mercury, though the nitrous gas unites with the oxygen as uſual, the mixture remains in the gaſeous or vaporous form for want of the contact of ſome fluid capable of abſorbing the new products. Conſequently the experiment muſt be made over water and not mercury.

The above experiments on the ſource of the reſidual azot and the deductions from them, have however been objected to by Berthollet, and every thing that comes from ſo excellent an obſerver deſerves attention, though we cannot conſider the objection as entirely valid. When nitrous gas is agitated with diſtilled water, a diminution of from 10 to 14 per cent. takes place, and as Humboldt has obſerved, nitrated ammonia is found in the water, which he attributes to the ſame cauſe as in the formation of the ſame compound by nitrous gas and a ſolution of ſulphat of iron, that is, to a decompoſition of part of the water, its oxygen ſaturating part of the nitrous gas to form nitric acid, and its hydrogen combining with the azotic impurity of the nitrous gas to form the ammonia. To this explanation Berthollet objects that the quantity of ammonia is extremely ſmall compared to that of the nitric acid produced; that if potaſh be diſſolved in the water the diminution of the gas is much ſpeedier and no ammonia whatever is formed, but only nitric acid, which is found in the form of nitrat of potaſh when the water is examined; that the electric ſpark, according to Van Marum, cauſes the abſorption of nearly three-fourths of the volume of the nitrous gas when over water, and the reſidue is azot; but when over mercury, only of about half its bulk; and from theſe and other obſervations he concludes that the azot left after all theſe operations is not a mere impurity of the nitrous gas, but is produced by the decompoſition of the nitrous gas itſelf. Thus he concludes that water, potaſh, the electric ſpark, &c. have the power of effecting a decompoſition of the nitrous gas neither by adding nor taking away any ſubſtance, but ſimply by concentrating the oxygen in one portion to its excluſion in the other. The portion in which the oxygen is concentrated is therefore converted to nitric acid, and that from which it is withdrawn is the reſidual azot gas. In further confirmation of this, the ſame chemiſt mentions that on expoſing nitrous gas to a cold ſolution of ſulphat of iron, and introducing phoſphorus to the reſidue, it did not diſſolve therein as phoſphorus does in pure azot, but only became ſoluble after a ſubſequent ſhaking with hydroſulphuret of potaſh, whence he would infer that nitrous gas is not ſo compleatly decompoſed by ſulphat of iron as by the hydro-ſulphuret.

It has been mentioned that Humboldt lays much ſtreſs on the comparative teſt with oxymuriatic gas, and finds (as his theory required) a greater reſidue with this teſt than with that of the ſulphat of iron. Berthollet however aſſerts that on operating with very pure nitrous and oxymuriatic gaſſes, adding the latter to the former very carefully to avoid the leaſt ſuper-ſaturation, the gaſſes ſo totally diſappeared that no more than from 1 to 2 per cent. of the volume of nitrous gas remained at all, inſtead of 14, which was Humboldt's reſult. The great defect of M. Berthollet's explanation of the cauſe of the azot is, that the ſource of the hydrogen of the ammonia, allowed on all hands to be produced by the mutual action between nitrous gas and ſulphat of iron, and even in a ſmaller quantity between nitrous gas and water, is totally unaccounted for, nor, according to the antiphlogiſtic ſyſtem of chemiſtry, is there any ſubſtance preſent except water that can furniſh it. If therefore ſome water is actually decompoſed and its hydrogen thus employed, there is a ſurplus of oxygen which may go either to the compleat acidification of the nitrous gas or to the compleat oxygenation of the *ſub-oxyd* of iron of the ſulphat. The other part of the valuable reſearch of Humboldt, conſiſting of many experiments with a view of finding the preciſe point of ſaturation between nitrous gas and oxygen, either pure or in atmoſpheric air, will be further noticed under the article Nitrous Acid, but it may be here mentioned that he conſiders this point of ſaturation of the two gaſſes to be (in bulk) from 2.6 to 2.5 of nitrous gas to 1. of oxygen, in which proportions, therefore, they form nitric acid.

Whatever may be the ſource of the azot left unabſorbed in the reſidue of nitrous gas, it appears by numerous experiments that nitrous gas *applied in a gaſeous form*, can ſcarcely be depended on as an accurate and comparable eudiometer, and that the number of precautions required to uſe it with tolerable accuracy is too great to give any encouragement to adopt it as an univerſal inſtrument.

Of nitrous gas diſſolved in a ſolution of iron.

The objections that prevail ſo powerfully againſt the uſe of nitrous *gas* do not apply in this caſe, and late obſervations have ſhewn that this teſt is the moſt expeditious and ſimple of

any known, and does not appear to yield to any in accuracy. Indeed it is no ſmall preſumption in its favour, that the reſults which it gives correſpond very cloſely with thoſe of the eudiometer of phoſphorus, hydroſulphuret, &c. whilſt the ſimple nitrous *gas* eudiometer always differs from the others in a very remarkable manner. In uſing this compound ſolution, no calculations relative to other gaſſes are required, but the abſorption of air, on mixture of the gas to be examined with the ſolution, ſimply indicates the quantity of oxygen contained in the air.

This eudiometer (firſt adopted by Mr. Davy)[1] is as ſimple as poſſible. The ſolution is made by paſſing nitrous gas through green ſulphat or muriat of iron diſſolved to ſaturation in water. As the gas is abſorbed the ſolution paſſes from olive green to a deep brown or almoſt black. A graduated eudiometer tube is then filled with the air to be examined, and put in contact with the ſolution, which by very gentle agitation will in a few minutes abſorb all the oxygen and leave the azot untouched. *(The moſt convenient apparatus for this and other eudiometrical proceſſes will be deſcribed in the Appendix.)* The only precautions required here are not to uſe the ſame ſolution twice, to keep it in a well-ſtopped bottle, and particularly to obſerve the time of the greateſt diminution when uſed, for ſhortly after, the volume of the reſidual gas begins again to encreaſe, owing perhaps to the decompoſition of the nitrous gas formed in the experiment. One cubic inch of the ſolution of moderate ſtrength will abſorb 5 or 6 cubic inches of oxygen, and therefore will be ſufficient to analyze about 25 inches of common air.

Of the ſulphurets as Eudiometers.

A mixture of iron filings and ſulphur moiſtened with a little water, and kept in a cloſe veſſel for about twelve hours, was the eudiometer employed by the illuſtrious Scheele in his original experiments on the conſtitution of the air ſo early as the year 1779. The ſulphur and iron unite by the help of the moiſture, and a ſulphuret is formed which has the power of very completely abſorbing the oxygen from the atmoſphere. With the ſimple apparatus of a ſmall cup of this mixture, ſupported on a ſmall pedeſtal in the midſt of a jar, graduated and ſtanding over water, this excellent chemiſt obſerved that an abſorption ſoon viſibly took place, and the water gradually roſe in the jar during about eight hours, after which no further riſe took place, and the entire contents were diminiſhed about 9 parts out of 33 (the entire capacity of the veſſel deducting the ſpace occupied by the cup) or about 27 out of 100. To aſcertain whether any notable change took place in the atmoſphere during the variety of ſeaſons through the year, he continued them with the ſame apparatus for a twelvemonth, but the abſorption was always from 24 to 27 per cent, without any connection with the apparent ſtate of the atmoſphere.

This is to be conſidered as a moſt valuable elementary experiment (and quite in the manner of this excellent philoſopher, that is, of doing great things with ſimple means) but circumſtances which he could not then foreſee render a more minute accuracy neceſſary to bring this teſt to the perfection of which it is capable. Dr. Prieſtley found that a mixture of moiſtened ſulphur and iron filings after a certain time produces a quantity of hydrogen gas, which, when the teſt is uſed eudiometrically, will mix with the azotic gas and enlarge the bulk of the reſidual air, thus giving the appearance of a leſs abſorption of oxygen than has really taken place. Hence the abſorption ſhould be regiſtered at the time of the greateſt diminution. The ſulphureted alkalies or alkaline earths are equally efficacious with the mixture of ſulphur and iron filings, and being in a liquid ſtate they may be ſhaken with the air, which will ſo much ſhorten the operation that five or ten minutes in this way of application will ſuffice, which is often a real convenience.

The ſulphuret of lime is made by boiling together ſulphur, lime, and water. For this purpoſe mix one ounce of flowers of ſulphur with a little pure water, put it into a glaſs matraſs and add about a quart more of water, and 3 ounces of lime broken into ſmall fragments; ſtop the veſſel looſely with a cork and boil gently for about an hour with frequent ſhaking. By ſubſidence the liquor ſoon becomes clear, and is then to be poured without delay into cloſe-ſtopped bottles. The liquid ſulphuret of potaſh or ſoda will anſwer as well, and theſe ſolutions may be made much more concentrated than the liquid ſulphuret of lime. The ſimple apparatus of Dr. Hope *(ſee the Appendix)* may be conveniently uſed in this eudiometrical proceſs. The air to be examined and the liquid ſulphuret of lime are ſhaken together for five or ten minutes, after which the abſorption is complete.

Guyton has propoſed to haſten the abſorption by heating the ſolution, but it appears that

[1] Journ. Royal Inſtitut.

with a very little exceſs of heat there is danger of getting a conſiderable admixture of ſulphuretted hydrogen.

Even in the cold, and when the proceſs has been put an end to as ſoon as the abſorption is complete, the reſidual azot muſt contain ſome ſulphuretted hydrogen, ſince it has the ſtrong ſmell peculiar to this gas, but the quantity is ſo ſmall, that though ſubſequent ſhaking with pure water will not free it from this ſmell, no perceptible diminution is found. The reſidual gas therefore may be eſtimated as entirely azot without danger of error.

A more important circumſtance has been mentioned by Marti[k], which if accurate, renders another precaution neceſſary. It appears from this that liquid ſulphuret of lime (and probably the liquid alkaline ſulphurets alſo) are capable of abſorbing a certain portion of azot as well as oxygen, if it has not previouſly been expoſed to air for a ſhort time. The quantity of azot thus abſorbed, however, is very ſmall, though ſufficient to make a very ſenſible difference in the calculation. By the experiments here given the abſorption of azot is in direct proportion to the quantity of the ſolution. Thus when one part of common air was ſhaken with 20 parts (in bulk) of the liquid, the abſorption was 26 per cent. but of theſe only 21 are found to be oxygen, and therefore 5 of azot are alſo abſorbed. To prove it, the experiment was repeated with the ſame ſolution that had ſerved for the previous experiment, and the abſorption was now only about 21 parts, ſhewing therefore that the ſulphuret had been ſaturated with azot by the former proceſs. The ſame ſolution was further ſhaken with pure azot but with no diminution of the latter, whereas when a freſh portion of the ſolution was uſed about .05 of the azot were abſorbed. With a perfectly freſh ſulphuret that had been cloſely kept from air till cold, and then uſed immediately, the abſorption of azot was much greater, for a twentieth of its bulk of common air ſhaken with it for a few minutes diminiſhed full one half, and conſequently the air had loſt both all its oxygen amounting to about 21 per cent. and alſo 29 of its azot. But it is never neceſſary to uſe ſuch a large proportion of the ſolution, a quantity equal to once or twice the bulk of the air being amply ſufficient, and for perfect accuracy it will therefore be adviſeable previouſly to ſhake it with a little common air, (or in a bottle which it only partly fills) after which it may be ſafely confided in, as being a very excellent and accurate eudiometer. The ſame obſerver alſo confirms the fact now ſo well eſtabliſhed, of the almoſt unvarying proportion of oxygen during all the ſenſible changes of the atmoſphere, by a ſeries of obſervations carried on for a long time at Altafulla in Spain, the above eudiometer ſhewing at all times from 21 to 22 of oxygen.

Of Phoſphorus as an Eudiometer.

Phoſphorus is capable of two modes of combuſtion when in contact with common air; the one, rapid, with evolution of great heat and light, the other ſlow, with the production only of white fumes ſtrongly luminous in the dark. The latter takes place when the temperature is not higher than about 90° or 100° (more or leſs according to the purity of the phoſphorus), and it is this mode which is chiefly uſed for eudiometrical purpoſes. It is ſimply and conveniently performed by fixing one end of a long thin cylinder of phoſphorus in a bit of a glaſs tube run through a cork which looſely fits the open end of the glaſs tube or narrow jar in which the air is contained, and immerſing the lower part of the jar in cold or cool water. As ſoon as the phoſphorus is in the tube, it becomes ſurrounded with a white fume, luminous in the dark, which ſlowly falls to the bottom and is abſorbed by the water, during which time the contained air gradually leſſens and the water riſes in the tube. The abſorption is compleat when the contained gas becomes clear and no longer luminous, which, in a ſmall tube with a ſtick of phoſphorus that traverſes nearly the whole length of its bore, and at a heat of about 70, requires from half an hour to an hour. The proceſs ſucceeds equally well though in a longer time at a lower temperature: a heat of about 80 or 90 is as much as the phoſphorus will uſually bear without actually taking fire, which may readily be avoided by obſerving that it melts and becomes gloſſy on the ſurface juſt before it kindles.

Several facts are to be noticed on this eudiometer, the exact operation of which has been aſcertained by Goettling, Berthollet, and other chemiſts. When phoſphorus is expoſed to air at any temperature below that at which it kindles, the firſt effect ſeems to be a ſolution of a minute portion in the azot of the ſurrounding air, and this phoſphorized azot then immediately unites with the oxygen, becomes thereby luminous, and phoſphorous acid abſorbable by water is generated. Hence it is (ſtrictly ſpeaking) the phoſphorus diſſolved in the azot that is the eudiometer in this inſtance,

[k] Jour. de Phyſ. tom. 52.

and in confirmation of this it may be obſerved that phoſphorus is not luminous in perfectly pure oxygen gas, but appears to remain quite inactive and untouched by it at any temperature below the point of kindling, after which indeed it burns with moſt intenſe heat and ſplendour. On the other hand if the pureſt poſſible azot is paſſed through water into a jar full of water and containing a ſtick of phoſphorus, the gas becomes luminous only for a very ſhort time (owing apparently to a minute quantity of oxygen abſorbed from the water) after which, when this is conſumed, the light ceaſes, but the azot continues to ſaturate itſelf with phoſphorus, and in ſo doing it expands about $\frac{1}{40}$ in bulk.[l] If now a bubble of common air or oxygen is let up to this phoſphorized azot (the phoſphorus itſelf being removed) the gas immediately again becomes luminous and continues ſo till the oxygen is exhauſted. By phoſphorus therefore we are furniſhed with a valuable teſt of the purity of azotic gas, for when this air is pure, no luminous vapours ſhould be produced, but at the ſame time a ſolution of part of the phoſphorus is effected, which is proved by afterwards throwing up a portion of common air and obſerving white luminous fumes. Berthollet has alſo obſerved[m] that when the azot remaining after the action of any ſulphuret on common air is put in contact with phoſphorus, it then does not acquire the property of being luminous with oxygen, and even if a liquid ſulphuret is placed in a veſſel full of azot already phoſphorized, it loſes the luminous property. This is a curious fact which merits further enquiry.

It has been queſtioned whether the above ſlow combuſtion of phoſphorus abſtracts the whole of the oxygen. After all abſorption has ceaſed, the apparent loſs is from 20 to 21 per cent. whereas in the eudiometers of liquid ſulphuret, and of the ſolution of iron with nitrous gas, the abſorption is generally from 21 to 22. Were this ſmall difference only obſerved in a few trials it might well be attributed to accidental variations and the degree of imperfection always attending theſe minute and delicate operations. But as the difference is conſtant ſome cauſe muſt be ſought for to account for it. It is certainly not at all improbable that no two eudiometric ſubſtances ſhould have preciſely the ſame affinity for oxygen, or ſhould agree in abſtracting every particle of it from the azot with which it is ſo intimately mixed in the atmoſphere. The valuable reſearches of Berthollet on the effect of proportional quantities in modifying chemical affinities render it highly probable that (rigorouſly ſpeaking) there is no ſuch thing as a perfect decompoſition of any actually exiſting chemical compound by the action of any ſimple ſubſtance, and the difficulties of accurate reſearch on gaſeous bodies are much greater than in any other kind of chemical inveſtigation. In the preſent caſe however part of the ſuppoſed incomplete action of the phoſphoric eudiometer may be ſhewn to be only apparent, from the circumſtance that the azot increaſes in bulk about $\frac{1}{40}$ by ſaturation with phoſphorus, which of courſe proportionally diminiſhes the apparent abſorption. For perfect accuracy therefore the bulk of the reſiduum muſt be diminiſhed by $\frac{1}{40}$, and this dimunition muſt be thrown in to the ſide of the oxygen abſorbed.

On the whole however, whenever the reſults of eudiometric experiments are given, the mode of aſcertaining the quantity of oxygen ſhould be expreſsly ſtated.

In analyzing an air much more oxygenous than the atmoſphere, the phoſphoric eudiometer is much leſs rapid and powerful in its operation, as the ſolubility of the phoſphorus decreaſes in proportion to the diminiſhed quantity of azot. Hence the other methods are preferable, or elſe the air to be examined may be diluted with azot or atmoſpheric air whoſe compoſition is previouſly known.

In theſe operations, as in all others on gaſſeous bodies, the corrections requiſite for variations in preſſure and temperature muſt be accurately attended to; there can be little doubt that many of the apparent anomalies found in all promiſcuous collections of experiments on gaſſeous bodies are to be attributed to this cauſe. The mode of making theſe corrections will be given under the article Gas.

EVAPORATION. That very important part of the theory of heat which is connected with the formation of vapour, has been deſcribed under the article *Caloric*.

As a part of technical chemiſtry the proceſs of evaporation is of extreme importance, as being eſſential to an infinite number of chemical proceſſes both for experiment and manufacture. As the conſumption of fuel is an object of firſt importance in all large evaporations, numerous experiments have been made to aſcertain the greateſt poſſible effect of combuſtibles in evaporating the watery part of ſaline and other ſolutions. It ſeems to be now well aſcertained that more liquid is evaporated by a given por-

[l] Berthollet. [m] Journ. Polytech. part. 3.

tion of fuel when the liquor is kept at the boiling point than at any inferior temperature, and hence this is the heat generally employed, except a lower temperature is required for particular purpoſes. Evaporation is greatly increaſed by the agitation of the air on the ſurface of the heated fluid, but again as this has an equal effect in cooling the whole maſs, it is a matter of great doubt whether the additional ſtrength of fire required to counteract this effect will not in moſt caſes deſtroy any economical advantage which may be propoſed from this circumſtance. For further practical obſervations on the conſtruction of veſſels for evaporation, the reader is referred to the article *Muriat of Soda*, and to the *Appendix of Chemical Apparatus*.

EXCREMENT *(Animal)*. Even this moſt diſguſting of all ſubjects has not eſcaped the minute reſearches of certain chemiſts. The cupidity of the alchemiſts was excited by ſome wild dreams of being able to extract from this ſubſtance an oil capable of fixing mercury (the firſt ſtep to its ſuppoſed converſion into gold), and hence many experiments were undertaken upon human excrement, on which ſubject we ſhall not detain the reader. Homberg (one of the moſt reſpectable of the earlier chemiſts, who were ſtill heſitating how much to reject of the fanatical viſions of the alchemiſts) made a number of experiments on this ſubſtance, one of the reſults of which was the diſcovery of the *pyrophorus*, which bears his name, and which is now made by a perfectly inoffenſive proceſs.

The dung of different animals is uſed for a variety of important purpoſes. That of the herbivorous quadrupeds appears a mixture of bile and animal fluids, with a conſiderable portion of the fibrous or leaſt digeſtible part of vegetable food. Hence the great uſe of camel's dung in Arabia and Egypt as fuel, being the chief and almoſt the only ſubſtance procurable for the purpoſe. A conſiderable quantity of ammonia is always produced by the burning of dung, from which, mixed with ſea-ſalt, the firſt ſal-ammoniac was procured. Cow-dung is of no ſmall uſe in a number of proceſſes for the preparation of cloth either for dyeing or bleaching. It mixes uniformly with water, and poſſeſſes cleanſing powers ſimilar to thoſe of ſoap. The excrement of dogs and carnivorous animals is diſtinguiſhed for its exceſſively offenſive ſmell and the extremely corroding effect which it has upon organized matter, when the putrid fermentation is eſtabliſhed. It is uſed in the preparation of LEATHER by *tawing*, as it is called, and its effect is firſt to looſen and deſtroy the adheſion of the hair, then to render the whole ſkin extremely flexible and open in texture, and if the proceſs is continued only a few hours too long, the whole conſiſtence of the ſkin is deſtroyed, and it falls to pieces like a mucilaginous jelly. If the proceſs of analyſis were leſs repulſive, the examination into the properties of this powerful agent would prove intereſting.

EXTRACT *(Vegetable)*. *L'Extractif*, Fr. *Extract-Auſzug*, Germ.

There are few terms uſed in a more vague and indeterminate ſenſe than that of extract. In common acceptation it is underſtood to mean that mixed maſs of vegetable principles which is *extracted* from almoſt all parts of plants, by maceration, infuſion, or decoction in water or alcohol, and evaporation of the ſolvent liquor to a greater or leſs degree of dryneſs. For example, when a ſtrong decoction of liquorice root is evaporated with due precaution, there remains at laſt a black ſweet coherent maſs, which is the common Spaniſh juice or *extract* of liquorice. The term extract therefore of itſelf only deſcribes the mode of formation, and that obviouſly by ſo general a term that a vaſt variety of vegetable principles may be included in it, all indeed that are ſoluble in the menſtruum employed. But beſides this general ſenſe of the term, modern chemiſts have alſo adopted it to expreſs one of the immediate principles, which there is good reaſon to ſuppoſe exiſts in all vegetables, poſſeſſes characteriſtic properties that diſtinguiſh it from mucilage, reſin, and the like, and forms a very large ſhare of all the common extracts, from whatever plants or parts of plants they are procured.

The preparation of the common extracts is peculiarly a branch of pharmacy, for the object for which this proceſs was invented was to concentrate in a ſmall and ſoluble maſs all the medicinal virtues of entire vegetables or parts of vegetables. Thus jalap root contains parts ſoluble in water and alcohol, in which the medicinal power reſides, but mixed with a large quantity of mere inert woody fibre, and hence an extract affords a means of ſeparating the former from the latter. The medical and purely pharmaceutical part of this ſubject, which includes a variety of important facts concerning the uſe and preparation of extracts, is foreign from the preſent object.

The general proceſs of preparing an extract where the menſtruum is water, is as ſimple as poſſible. The ſubſtance employed is firſt bruiſed, raſped, or divided in any other way, then boiled with water once or oftener, ſo as to make a

very ſtrong decoction, which is then evaporated generally by a boiling heat, till of a thick treacley conſiſtence, after which it is dried to the degree required over a ſtove, or in ſome gentle heat to avoid the burning and conſequent deſtruction of the medicinal powers, which would enſue were not the heat moderated. The particular precautions required for certain of theſe extracts need not here be enumerated.

The ſpirituous extracts, or thoſe in which the menſtruum is alcohol more or leſs diluted, are prepared in the ſame general way. As the ſubſtance extracted by alcohol is chiefly reſin, theſe extracts are often called reſinous extracts or artificial reſins.

When the vegetable employed is a ſucculent herbaceous plant, the extract is often made without the addition of water, merely by putting the freſh plant under a ſtrong preſs, forcing out all the natural juice, and evaporating it ſlowly to the due conſiſtence. The extract of hemlock is made in this way. Theſe preparations are alſo called with more perfect accuracy *Inſpiſſated Juices*. The gum reſins are properly the native juices of plants, inſpiſſated by the evaporation of the watery part either in the ſun's heat or by artificial fire, or ſometimes by both. The catechu is an inſpiſſated juice of this kind, and is compoſed chiefly of tan brought to a ſtate of dryneſs.

Chemiſtry is indebted to Fourcroy for a very valuable reſearch into the purely chemical nature of extract, contained in his elaborate analyſis of the cinchona of St. Domingo: [a] and to Vauquelin [b] for an excellent enquiry into the ſame ſubject connected with the analyſis of the ſap and native juices of the ſucculent plants. All theſe memoirs throw much light on the nature of extract, though many difficulties ſtill remain.

Fourcroy's operations on the cinchona, as far as relates to extract, are the following. A pound (16 ounces) of the cinchona reduced to powder was boiled twelve times ſucceſſively for a quarter of an hour, in about 26 lb. of water each time. The firſt decoction was of a deep brown red, very bitter, and ſtrongly frothed in boiling. It yielded by evaporation in a gentle heat 5 oz. 7 grs. of a brown dry extract. The ſecond decoction was much leſs coloured, and gave only 9 drams of extract: the third gave only 2 grs.; and the ſenſible qualities of each decoction regularly diminiſhed to the twelfth, which was little elſe than pure water. The entire quantity of extract obtained was 9 oz. 56 grains. A ſecond ſeries of decoctions was made in preciſely the ſame way and with the ſame quantities, but with this difference, that each decoction was allowed to cool before evaporation, in which time the ſix firſt depoſited, in decreaſing proportions, a quantity of black tenacious extract, apparently inſoluble in cold water. The ſupernatant liquors were then united, and the whole evaporated to 2 lbs. and the depoſit on cooling was added to the other extracts, which all together amounted to almoſt 2 ounces leſs than the quantity obtained in the former way, which therefore remained in the 2 lbs. of decoction. This laſt on mixture with alcohol depoſited about an ounce of a whitiſh coheſive maſs, evidently different from the black extractive depoſit, and was mucilage. Alcohol therefore appearing a uſeful reagent in this analyſis, the black extract ſeparated from the decoctions by mere cooling was treated in this way, to determine whether it was ſimple or compounded. Accordingly alcohol was boiled on it, and diſſolved all but about $\frac{1}{20}$, which remained in the form of a fine red powder. This laſt digeſted with cold water loſt a third of its weight of mucilage, ſimilar to that precipitated from the decoction, and the remainder was, as before, a fine red powdery ſubſtance, the nature of which will be preſently mentioned. The alcoholic ſolution was then let to ſtand expoſed to air for ſome days, when it depoſited a ſmall quantity of brilliant cryſtalline grains. It was then mixed with water, and in ſome hours there ſeparated a number of white flocculi. Laſtly, the alcohol and water were totally evaporated, and a large quantity of extract remained. By repeating this mode of analyſis with the entire extract obtained by the firſt proceſs (which was therefore the whole of the matter which a pound of cinchona would yield by boiling with water to exhauſtion) all the above ſubſtances were obtained in the following proportions:

	oz.	gros.	grs.
Mucilage	1	1	0
Cryſtalline grains ſeparated from the ſolution	—	1	0
Flocculi ſeparated by adding water to the ſolution	—	1	12
Red powder inſoluble in alcohol	—	2	0
Extract left at laſt	7	0	44
Loſs	—	3	—
	9	0	56

[a] An. Chim. tom. 8. & 9. [b] Ditto, tom. 31. and Memoire ſur le principe Extractif. Jour. de Pharmacie, p. 132.

It appears therefore that the extract is in by far the greateſt proportion, which, with the red powder, are the only ſubſtances to be particularly conſidered in this place. It may be juſt added that the mucilage very cloſely reſembled the common gum-mucilages, the cryſtalline grains were inſoluble in alcohol and in cold water, but yielded to a large quantity of boiling water, diſſolved in the alkalies and gave ſome ammonia by diſtillation; but the exact nature of this ſubſtance is not known, and the flocculi reſembled in every reſpect the gluten of wheat.

The red powder the author ſhews to be clearly different from reſin or any of the ſuppoſed immediate vegetable principles. Though its inſolubility in water would make it approach to the nature of reſin, its equal inſolubility in alcohol refutes this conjecture. Neither does it melt at a gentle heat, but it unites with alkalies immediately and inſeparably, in both of which properties it differs from reſin. Its colour is extremely durable and little altered by the oxymuriatic acid. The true nature of this red powder ſeems to be in a good meaſure explained by that of the extract.

This extract is obviouſly from its quantity and its ſenſible properties the moſt important of the ſoluble parts of the cinchona. When quite dry it is hard and brittle and ſhining in its fracture, of a black or deep brown colour, and intenſely bitter. Neither gum nor reſin reſembles it in the united properties of being ſoluble totally and permanently in hot alcohol, and inſoluble in cold water, but diſſolving entirely in hot water, with the ſeparation of the greater part (but not the whole) on cooling, unleſs largely diluted. The oxymuriatic acid was tried as a reagent on a ſmall portion of this extract diſſolved in a large quantity of water. The firſt effect of the acid paſſed in the form of gas through the ſolution, was to give it a clear red colour and to ſeparate a red flocculent powder. A greater quantity of the gas deprived the liquor of colour and much lightened that of the powder. After ſeparating all the red flocculi, which amounted to $\frac{1}{7}$ of the extract originally employed, the liquor now ſaturated with the gas gave by evaporation a black acerb matter mixed with muriatic acid.

This extract therefore appears by this analyſis to be compoſed of two parts, one capable of being converted by oxymuriatic acid into a red pulverulent ſubſtance, and the other not acted on by this ſubſtance. On examining the above red powder it was found alſo to reſemble very cloſely the red powder mentioned above as one of the conſtituents of the cinchona. The author therefore concludes that this laſt conſiſts of the true extract altered by abſorption of oxygen, ſince a ſimilar powder is produced by the direct action of oxymuratic acid on extract; and infers that the oxygenation in the former caſe is produced by the gradual action of the atmoſphere on the ſurface of the decoction during the long expoſure in the time of evaporation. In confirmation of this hypotheſis he adds that the quantity of this red inſoluble powder generated, is in direct proportion to the time of expoſure to air, and hence as it appears to be nearly inert on the human conſtitution, it has been lately thought proper in pharmacy to avoid this deterioration of the extract by boiling the decoction only for a few minutes and in a covered veſſel.

Extract when heated *per ſe* to decompoſition gives, beſides the uſual vegetable products, a ſmall quantity of ammonia, which indicates the preſence of azot, but whether this is an eſſential part of extract, or only ariſes from ſome adhering portion of gluten, is very doubtful.

A very pure extract has long been known in pharmacy by the name of *Eſſential Salt of Count la Garaye*, who firſt conceived the idea of preparing the ſuppoſed eſſential or finer part of the ſoluble matter of cinchona and other ſubſtances by infuſion in cold water, aſſiſted by extreme and long continued agitation. This laſt was firſt performed by ſmall mills and a very complicated apparatus, but was afterwards found unneceſſary. This preparation is made ſimply by adding cold water to the powdered bark, ſhaking them together frequently during a maceration of two days, and then ſlowly evaporating the infuſion, which is ſtrongly impregnated with the ſenſible and active properties of the cinchona. The extract thus prepared, if the evaporation be well managed, has a fine granular cryſtalline appearance, whence the inventor took it for an eſſential ſalt. It is ſcarcely ſoluble in cold water and a good deal reſembles the red powder, the ſuppoſed oxygenated extract; but it has not been examined in a very ſatisfactory way.

The above are the general properties of the extract obtained by the decoction of the peruvian bark, and will apply with ſome latitude to that of moſt other barks and woods. With many, however, a large portion of tan is mixed which may be ſeparated by ſolution of iſinglaſs, or any other gelatin.

We proceed to the properties of the extract as contained in the native juices of plants, and therefore probably in a purer ſtate, at leaſt being already in a ſtate of ſolution, all the changes liable to be produced by decoction with water

are avoided. The experiments of Vauquelin on this ſubject are here of chief importance *(ſee the article* SAP*)*. When the ſap of any tree is firſt drawn, it is always colourleſs or nearly ſo, but in the proceſs of evaporation it invariably becomes brown, and a certain though ſmall quantity of pulverulent inſoluble brown or red matter is precipitated. The extract obtained by evaporation to dryneſs is always a very mixed ſubſtance, containing, often tan, often ſaccharine mucilage, and always ſeveral earthy and ſaline matters, among which are lime, potaſh, acetous acid, and generally ammonia. The exiſtence of acetous acid in all extracts whatever, is aſcertained by pouring a few drops of ſulphuric acid upon them, which immediately produces a pungent agreeable vapour of acetous acid, and with ſufficient quantities this acid may be collected in a receiver.

Ammonia is alſo diſcovered in extracts, for if ſome quick-lime be rubbed with any of them, the vapour of this alkali immediately ariſes. All the extracts made by water conſtantly attract moiſture from the air, whereby in no great length of time they grow mouldy, to the great detriment of their medicinal virtues. This diſpoſition to moiſture is doubtleſs principally owing (as Vauquelin has obſerved) to the acetite of potaſh and ammonia which they contain, and which are very deliqueſcent ſalts.

All the ſoft extracts have alſo an exceſs of this acid, and hence they invariably redden litmus.

Extract appears to form a great portion of the colouring matter of vegetables, the affinity of which with different mordants, has been amply detailed under the article Dyeing. Thus if a ſolution of alum be added to any extract diſſolved in water, a copious coloured precipitate is formed, inſoluble in water, and conſiſting of extract intimately combined with alumine, whilſt the ſupernatant liquor is rendered nearly colourleſs. Moſt of the metallic ſalts alſo occaſion a precipitate conſiſting of the extract with the metallic oxyd. The colour of the greater number of extracts is brown, red, or fawn.

From the foregoing obſervations it appears to be as clearly demonſtrated as in any other caſe of vegetable analyſis (in itſelf difficult and complicated) that there exiſts a peculiar and immediate vegetable principle to which the term extract may be given, that it is almoſt invariably contained in greater or leſs degree in the part which is ſoluble in water, that it is naturally colourleſs when in ſolution in the vegetable juices, but when condenſed in the ſolid parts, or when expoſed to air, or to heat, it always becomes more or leſs brown and coloured, that it is freely miſcible with water in the ſtate of colourleſs ſolution, but when altered by long expoſure to heat and moiſture it becomes ſcarcely ſoluble in cold water, and much of it ſpontaneouſly ſeparates from its ſolution by hot water, in proportion as it parts with heat; that it has a very ſtrong affinity for alumine and metallic oxyds, ſeparating them from their reſpective ſolutions, and forming compounds ſcarcely decompoſable but by the agency of fire; and laſtly that it is found by deſtructive diſtillation to be compoſed of carbon, oxygen, and hydrogen, and probably a ſmall portion of azot. Theſe chemical properties are ſufficient to diſtinguiſh it from every other of the immediate vegetable principles, but to them is added by ſome acute and excellent chemiſts, another characteriſtic namely, a ſtrong affinity for oxygen, to which the colouring and difficult ſolubility in water are attributed. This character, however, cannot be admitted without ſome limitations.

When a colourleſs juice, ſuch as the ſap of any tree, is heated in an evaporating veſſel, it gradually becomes of a dark brown, owing, as it is ſaid, to the oxygen which the extract abſorbs from the air. This opinion is certainly of itſelf ſufficiently probable, but it alſo appears that the ſame change of colour takes place in veſſels nearly cloſed as ſoon as the juice becomes heated, for Vauquelin[c] adduces this as a convincing argument to ſhew that it does not depend on a concentration of the extract. But it is difficult to conceive how ſufficient oxygen ſhould be acquired for this purpoſe from the narrow aperture of a veſſel through which a quantity of heated vapour muſt be conſtantly expelled; and if the firſt change will take place independant of the effect of the external air, it deſerves inquiry by experiment, whether an extract ſimilar to that produced by evaporation in open veſſels, would not be obtained by the ſame proceſs in cloſed veſſels. Again, the chief argument adduced for the ſucceſſive oxygenation of extract, is the formation of the red-brown pulverulent and ſometimes cryſtalline depoſit, from the watery ſolution of extract after long evaporation in open veſſels, confirmed by the immediate production of a ſimilar depoſit by the oxymuriatic acid. But it has not yet been at all proved by analyſis that this depoſit differs from extract in no other circumſtance than in an increaſed quantity of oxygen. The exact

[c] Jour. de Pharmacie.

nature of this ſingular product ſtill requires further explanation, but it appears to be a very intimate union of vegetable matter with lime, for when calcined, the reſidue is chiefly carbonat of lime. Neither is the production of this ſubſtance by paſſing oxymuriatic acid through a ſolution of brown extract, concluſive of its being generated by the ſimple union of oxygen with extract, without being confirmed by a full examination of the ſolution that remains, and a proof that all the oxygen of the acid had paſſed into the red powder, and into that only. It cannot be doubted that in the courſe of common evaporation of the decoction or infuſion of extract, the length of time to which it is expoſed to air much influences the quantity of this ſuppoſed oxygenated extract, but though the abovementioned eminent chemiſts expreſs their full conviction that the whole extract might be ſucceſſively changed in this manner, it does not appear that they have ever effected this change even on any conſiderable portion of the extract, for in the experiments with oxymuriatic acid, after this had been added to full ſaturation, only 30 grains of the red powder could be obtained from 72 of the extract. This opinion therefore of the ſpontaneous oxygenation of extract though ingenious, and by no means improbable, muſt ſtill be conſidered as extremely hypothetical, and cannot be yet admitted as a diſtinctive character of this vegetable principle.

Much variety is found in the ſenſible properties of colour and taſte, in the different extracts. The colour is generally brown or red with various modifications, and it is quite a characteriſtic of all the ſolid extracts to be deeply coloured, in which reſpect they differ eſſentially from mucilage, fecula, and many other vegetable principles.

Bitterneſs of taſte is a much leſs conſtant character, and is even entirely abſent from a very large number of individual extracts.

After all that has been done on this ſubject there is ſtrong reaſon to ſuſpect that this ſubſtance is one of thoſe which the moſt eaſily enters into combinations with all the other vegetable principles, and probably unites with them ſo ſtrongly, that no chemical proceſs has ever ſucceeded in producing it pure and unmixed.

F

FAHLERZ is an ore of COPPER, which ſee.

FARINA. See FECULA.

FAT. For the properties of this ſubſtance ſee the articles OIL, *animal*, and SEBACIC *Acid*.

FEATHERS. The chemical compoſition of feather appears to be nearly the ſame as of hair, nail, cuticle, and cuticular ſhell, that is (according to Hatchett's admirable reſearch on theſe ſubſtances [a]) to conſiſt of little elſe than inſpiſſated albumen, mixed with a very minute portion of gelatin. The latter however is ſo ſmall that quill or feather freed from adhering oil, may be boiled for many days in water without any apparent alteration, the liquor having no ſenſible properties, giving no precipitate with tan, and a very ſmall one with nitro-muriat of tin. It is therefore only a very minute portion of gelatin that is extracted in this way. (See ALBUMEN.)

FECAL MATTER. See EXCREMENT.

FECULA. The term Fecula is generally applied to any fine pulverulent matter extracted from any part of a vegetable, ſimply by breaking down its texture, waſhing with water, and ſubſidence for a greater or leſs time. The fecula is the ſubſtance depoſited at the bottom of the water. It is therefore in other words a moſt minutely divided ſubſtance, capable of being for a time ſuſpended but not diſſolved in cold water or in the native vegetable juices. Of theſe the moſt important is the *Amylaceous Fecula*, or a nutritive inſipid ſubſtance which is contained moſt abundantly in all grains forming the largeſt and moſt valuable part of their ſubſtance, and when ſeparated, purified, and dried, is the common STARCH. The preparation of ſtarch as a manufacture, will be deſcribed under that article, the chemical properties of pure fecula belong to the preſent ſubject.

Almoſt every part of vegetables will furniſh this fecula, but it is particularly found in all grains or ſeeds of whatever kind, is united in them with an extractive and ſaccharine matter, ſometimes with gluten and vegetable albumen, with mucilage or with oil. It is alſo contained copiouſly though comparatively in leſs proportion in moſt roots, particularly the tuberous and bulbous, in the medullary part of trees and plants, and ſometimes nearly equally diffuſed over the whole plant as in many of the lichens and plants of a ſimilar genus.

The extraction of the fecula is a very ſimple proceſs, but from certain vegetables it can never

[a] Ph. Tranſ. vol. 90.

be obtained free from colour and taſte. The root or grain employed muſt firſt be thoroughly bruiſed, raſped, or broken down in any way, and then waſhed with a quantity of cold water, which becomes immediately turbid, and if the fecula is white, milky; and ſimply holds the fecula ſuſpended in a ſtate of extreme diviſion, but without diſſolving any portion of it. This turbid water is then to be immediately ſeparated from the fibrous pulp by a ſieve, and allowed to remain at reſt for a time, when the fecula will be found at the bottom, in the form of a very fine cloſe-grained powder, but without any tenacity or coheſion, ſomewhat of the conſiſtence of very fine wetted ſand. It ſhould then be waſhed repeatedly with abundance of water, till this comes from it quite inſipid.

The extraction of fecula is therefore as ſimple as poſſible, conſiſting in fact only of a ſingle operation, that of waſhing out with cold water, but it is only from grains and ſome roots that it can be procured ſo eaſily, for this ſimple method will not ſucceed in the nut or kernel ſeeds, in which the mixture of oil, fecula, and mucilage is ſo intimate, that both diſſolve together into a milky emulſion when agitated with water; nor will mere waſhing eaſily ſeparate the fecula from many of the juices, fruits, and ſoft parts in which it is intimately combined with mucilage, extract, and ſaline ſubſtances.

In all proceſſes for the ſeparation of fecula from other vegetable matters, it ſhould be conſtantly kept in mind that only *cold* water is to be employed, for when hot it diſſolves readily.

Pure fecula (taking ſtarch for an example) is a white powder nearly if not abſolutely inſipid, ſomewhat adhering to the tongue, but readily ſoftening down in the mouth into an incohering pulp. When examined with care in a ſtrong light, and eſpecially with the help of a lens, it is ſeen to be compoſed of ſmall ſemi-tranſparent globules, with a ſattiny gloſs [b] and ſomewhat of a cryſtalline arrangement. When in maſs and ſqueezed between the fingers, it breaks with a ſlight ſnap and a peculiar ſhort feel not eaſily deſcribed. It is not eaſily moiſtened with cold water, on the ſurface of which it ſwims till thoroughly wetted.

Pure ſtarch when heated ſtrongly in the open air, paſſes from yellow to red and brown, ſoftens, puffs up, exhales a white, pungent, acid-ſmelling ſmoke, exactly reſembling that of mucilage or ſugar, and leaves a ſpongy and rather bulky coal. The products of its diſtillation are, a water loaded with pyromucous acid, ſome drops of a red or brown oil, much carbonic acid and hydrocarbonous gaſſes. The coal when fully calcined leaves ſlight traces of potaſh and phoſphat of lime.

Starch does not eaſily alter in the air, but by very long keeping it runs into clots, and gets a ſour and rancid ſmell.

Fecula rubbed with a little cold water only makes an incoherent maſs, which on drying cracks into ſmall pieces. With more water and a moderate warmth the mixture ferments faintly, and turns ſour, probably by producing the acetous acid.

Boiling water however acts in a very different manner on fecula, for it ſpeedily and totally diſſolves it into a thick, tenacious, tranſparent gelly, as is daily ſeen in the domeſtic uſes of ſtarch. This gelly becomes thicker and more tenacious by long boiling, and it will unite with boiling water in any proportion.

By ſlow evaporation the gelly ſhrinks in every direction, and at laſt dries into a nearly tranſparent brittle ſubſtance, ſo cloſely reſembling the evaporated ſolution of mucilage, that ſcarcely any difference can be found between the two.

The gelly when much diluted and dried on very extended ſurfaces gives only a kind of varniſh and ſtiffneſs, for which it is of great uſe in the ſtarching of linen.

Moſt of the acids diſſolve fecula readily, eſpecially when hot, and with nearly the ſame appearances that attend their action on mucilage and ſugar. The nitric acid however does not produce with fecula the *Mucous* acid, as it does with gum mucilage.

The alkalies diſſolve fecula with eaſe, but without appearing to produce any material change in its compoſition.

On the whole the reſemblance between the amylaceous fecula and mucilage is ſo ſtrong, that they may almoſt be conſidered as identical when each is brought to a ſtate of ſolution in water.

Of the Green Fecula of Plants.

A vaſt number of the green ſucculent plants when expoſed to ſlight preſſure, give a very turbid green juice, from which a fecula ſubſides though extremely ſlowly, but it may be ſeparated more readily by the filter. In this caſe the filtered liquor is tenacious, but clear and colourleſs, and a green pulp is left on the filter. Rouelle [c] appears to have been the firſt who clearly ſhewed the nature of this fecula, and proved it to be not in the leaſt ſimilar to the amylaceous fecula, but to be compoſed of a ſubſtance re-

[b] Fourcroy Syſt. de Conn. Chim.

[c] Procédés du Regne Vegetal, &c.

ſembling the gluten of wheat, intimately combined with a kind of reſin ſoluble in alcohol, to which the green colour ſeems to be owing. The clear liquor from which this fecula has ſubſided alſo holds in ſolution another portion of gluten, or a ſimilar matter.

Fourcroy conſiders this fecula rather as albuminous, and the ſubſtance contained in the clear liquor to be ſtill more decidedly ſo, but Prouſt[d] has pointed out ſome differences, and the other obſervations of this excellent chemiſt on this ſubject are alſo important.

When any of the green turbid juice of plants, ſuch as of cabbage, hemlock, creſs, and the like, is expoſed to heat, it coagulates or becomes ropy, and ſoon a conſiderable quantity of a green tough glutinous maſs ſeparates in flocculi from the liquor, which is then left colourleſs. The clear filtered recent juice of plants alſo affords flocculi of gluten, which readily ſeparate at a heat as low as 145°. At this temperature the albumen of an egg mixed with water will not coagulate. When the coagulated maſs dries, it hardens into an elaſtic horny ſubſtance, which will not again unite with water. If this fecula either before or after coagulation by heat be kept under water, in warm weather it becomes offenſive in a day's time, and by keeping it grows exceſſively putrid, with the fetor attending animal matter in a high ſtate of decompoſition. It appears to be to this that the exceſſive putreſcency of hemp is owing whilſt it is rotting in ditches to prepare it for ſpinning. The water in which this fecula has been long kept contains ſulphuretted hydrogen, carbonat of ammonia, and ſome gluten diſſolved in the ammonia.

To ſhew more decidedly that it is a kind of gluten rather than albumen which gives alſo to the liquor which holds fecula in ſuſpenſion thoſe chemical properties belonging peculiarly to animal matter, Prouſt made the following comparative experiments, taking the white of egg as the example of the pureſt albumen, and clear filtered cabbage juice for the other. Two matraſſes were filled, the one with the cabbage juice, the other with ſome of a liquor made of the white of an egg beat up with a pint of water. On immerſing them in water heated to 145°, the juice directly became turbid with cheeſe-like flocculi which fell to the bottom, but the albuminous water remained unchanged. Two more veſſels were filled, one with the egg-water and the other with the juice diluted with twenty parts of water, and were ſlowly heated to ebullition. In the latter the fecula ſeparated totally from the water, but the egg-water only became opaleſcent, but not curdy, nor did it ſeparate from the water, for albumen much diluted cannot by mere heat be freed from the water with which it is mixed. The albuminous water alſo keeps for ſome days clear and unaltered in a common temperature, but the diluted cabbage-juice turns putrid and begins to be curdy in a very ſhort time, and ſooner or later all the gluten is ſeparated ſpontaneouſly in this way. Albumen alſo turns the red vegetable juices green, but the recent cabbage juice turns litmus red, and the waſhed fecula produces no change at all. Alcohol ſeparates part of the albumen from the water in thin flocculi, but added to the juice it cauſes a heavy white powder to precipitate. All the acids, hydroſulphurets, and ammonia ſeparate the feculous gluten from the juice but produce no change on albumen. No ſalt can deprive water of albumen, but this fecula on the contrary is precipitated from its watery ſolution by almoſt every ſaline ſubſtance. The feculæ of moſt of theſe plants generally dry to a brown hard maſs, but dried albumen reſembles horn. From all examinations this kind of fecula is chiefly compoſed of a part nearly if not abſolutely identical in nature with the gluten of wheat or blood.

The green fecula when put into potaſh partly diſſolves therein, the inſoluble portion falling to the bottom as a green ſediment. The ſolution has all the characters of animal matters, exhaling ammonia, and blackening ſilver and many other metallic ſolutions.

When the entire green feculous precipitate, formed by heating the recent juice, is treated by alcohol, a portion only diſſolves therein, leaving the true gluten untouched, and which amounts to about 80 per cent. of the entire precipitate. The alcoholic ſolution evaporated to dryneſs leaves (as Rouelle firſt obſerved) a ſoft green ſubſtance reſembling a reſin. Alcohol alſo added to the juices gives a precipitate of gluten, and unites with the reſin. It has been doubted however by Parmentier whether this green *reſin* is properly ſo called, ſince it does not depoſit any thing on mixture with water as the tinctures of the true reſins do. The oxymuriatic acid in a few days takes away all colour from this green reſin, makes it ropy like turpentine, and its ſolution in alcohol will then grow turbid with water. The entire green fecula is reduced by oxymuriatic acid to the colour of dead leaves. The above reſin gives a

[d] Journ. de Phyſ. tom. 36.

clear ſolution with potaſh, and this colour will attach itſelf to ſilk, but it is not permanent.

On the whole therefore there is much reaſon to believe that the green fecula of plants conſiſts of gluten intimately combined with a ſubſtance very nearly reſembling a reſin, and that it is to the former principle that the tendency to animal putrefaction and the ammoniacal products are owing, and in the latter the green colour ſeems entirely to reſide.

See further the article GLUTEN.

FELSITE. See FELSPAR *(Compact)*.

FELSPAR.[a] *Feldspath.* Germ. and Fr.

Of this mineral there are the following ſubſpecies, viz. Adularia, Common Felſpar, compact Felſpar, continuous Felſpar, Labradore Felſpar.

1. ADULARIA *Adular*, Wern. *Moonſtone*, Kirw. *Feldſpath nacré*, Hauy.

The colour of adularia is yellowiſh, greeniſh, or milk-white, and in certain directions it exhibits a play of ſilvery and pearly colours, owing to the different reflections of light from the laminæ of which it is compoſed. It occurs either in maſs or cryſtallized. Its primitive figure is an irregular oblique angled parallelipiped, of which the faces in two directions are ſmooth and well defined and form an angle with each other of 90°, while the faces in the third direction are uneven, and form with the others angles of 120°. and 111.° 28′. Beſides this, its primitive figure, it preſents alſo the following modifications.

1. An oblique four-ſided priſm bevilled on two of its oppoſite ſides.

2. An oblique four-ſided priſm with dihedral ſummits.

3. A ſix-ſided priſm with dihedral ſummits.

4. A double cryſtal, in the form of a rectangular four-ſided priſm compoſed of two half cryſtals united together in oppoſite directions.

5. A quadruple cryſtal, compoſed of four cryſtals of var. 2. united together by their ſummits and mutually penetrating each other, forming a kind of croſs, conſiſting of four triangles united round a common centre.

The ſurface of the cryſtals is ſmooth and often ſtriated longitudinally. They are for the moſt part middle ſized or large. The external luſtre is ſhining and ſomewhat pearly: the luſtre of the principal fracture is bright ſhining; of the croſs fracture ſhining, between vitreous and pearly. Its longitudinal fracture is perfectly foliated, its croſs fracture is ſmall conchoidal. It breaks into rhomboidal fragments. It is compoſed ſometimes of ſtrait lamellar diſtinct concretions. It is tranſlucent paſſing into tranſparent. Its hardneſs is inferior to quartz, but greater than that of common felſpar. It is eaſily frangible. Sp. gr. 2.5 to 2.6.

When expoſed to the blowpipe without addition it crackles a little, and at length melts into a whitiſh glaſs.

It has been analyzed with the following reſults by Chenevix and Vauquelin.

	Chen.		Vauq.
Silex - -	64.	—	64.
Alumine -	24.	—	20.
Lime - -	6.25	—	2.
Oxyd of iron	2.	—	0.
Water - -	1.75	—	0
Potaſh - -	0	—	14
	98.00		100.

Adularia was firſt found by H. Pini in the mountains ſurrounding Saint Gothard in Switzerland, eſpecially in the ſummit called Mont Adula (whence its name). It here occurs in cryſtals, lining the cavities of gneiſs and micaceous ſchiſtus. This mineral is alſo ſaid by Jameſon to occur in the Iſle of Arran. The moon-ſtone of Ceylon, and a mineral diſcovered in Languedoc by M. Dodun and named by him *œil de poiſſon* (argentine felſpar of Kirwan) are alſo conſidered as varieties of adularia.

II. COMMON FELSPAR. *Gemeiner Feldſpath*, Wern.

The colour of this mineral is milk-white, yellowiſh, greyiſh and reddiſh white; alſo wax yellow and ochre yellow; fleſh red, blood and brick-red; leek green, mountain green, and ſometimes though rarely verdigris-green. It occurs in maſs, diſſeminated, in rounded fragments or cryſtallized. Its primitive form and the other varieties of cryſtallization that it aſſumes are the ſame as thoſe of adularia: it has alſo been found in ten-ſided priſms with dihedral or other variouſly modified ſummits. The cryſtals are for the moſt part ſmall and middle-ſized. Externally felſpar is more or leſs ſhining; internally it is the ſame, with a luſtre between vitreous and pearly. The longitudinal fracture is perfectly lamellar; the croſs fracture is fine grained uneven paſſing into ſplintery. Its fragments are rhomboidal with only four ſhining faces, the other two being nearly dull. It varies from tranſlucent to opake. It occurs often in granular concretions, either large or ſmall. It

[a] Hauy, Brochant, Kirwan, Jameſon.

is not so hard as quartz, yet will scratch glass: it is brittle and easily frangible. Sp. gr. 2.27 to 2.70.

It melts before the blowpipe without addition into a white somewhat translucent glass.

Felspar has been often analysed and with very different results. The three last analyses of this substance and perhaps the most to be depended on, are, one of common felspar and another of felspar from the sand of Ceylon, by Chenevix, and one of the green Siberian felspar by Vauquelin.

	Com. F.	Ceylon F.	Siberian F.
Silex - -	64. —	68.5 —	62.83
Alumine -	24. —	20.5 —	17.02
Lime - -	6.25 —	7. —	3.
Oxyd of iron	2. —	1.5 —	1.
Potash - -	0 —	0 —	13.
	96.25	97.5	96.85

Felspar when exposed to the weather acquires gradually an earthy appearance, and at length passes into porcelain clay. It also occurs in a state of semi-decomposition in several varieties of granite and porphyry, where it cannot have been affected by the atmosphere. When in this state it is usually of a yellowish or reddish-white colour, a faintly glimmering lustre, and a fracture imperfectly foliated passing into earthy: it breaks into indeterminately angular fragments, is opake and considerably softer than common felspar. A very light coloured variety was analysed by Vauquelin, and found to contain

Silex - - -	74
Alumine - -	14.5
Lime - - -	5.5
	94.0
Loss - -	6
	100.

Some of the coloured translucent varieties of felspar contain particles of mica dispersed through their substance, and these when the stone is exposed to the light form so many luminous points, which relieve the colour of the felspar and give the whole a spangled appearance that has a pleasing effect: in some instances however these brilliant particles seem to be occasioned merely by fissures in various directions. When felspar exhibits this appearance it is called *Aventurine* (a term also applied to a similarly glittering variety of Quartz). The green Siberian felspar sometimes contains spangles of a remarkably brilliant silvery mica, forming a very elegant aventurine. Another fine variety has been procured from Cedlovatoi, an island in the White Sea, not far from Archangel, consisting of a semitransparent hyacinth-brown base with gold coloured spangles. The aventurine of Spain is the most familiar to European lapidaries, but this is a variety of quartz.

Common felspar is the most generally diffused, both as to its local and geological situation, of any other mineral except perhaps quartz. It is an essential constituent of granite and gneiss, and frequently occurs in micaceous and argillaceous schistus: it forms a large proportion of all silenite, and is contained abundantly in almost all porphyries: it is occasionally though rarely found in primitive limestone: it abounds in primitive, transition and secondary grünstein, and frequently though in smaller proportion in most of the other rocks belonging to the trap-formation: it also abounds in the greater part of the real lavas.

III. Compact Felspar. *Dichter Felspath.* Emmerl. *Felsite*, Kirw.

Its colour is bluish white passing into sky-blue, or greenish-white passing into brownish-green. The blue variety occurs in mass, the green is either disseminated or crystallized. Its lustre is glistening. Its fracture is very imperfectly lamellar approaching to splintery: its fragments are indeterminately angular: it is feebly translucent, and though hard considerably inferior in this respect to quartz.

Before the blowpipe it is difficultly fusible without addition, into a frit or imperfect glass. It has not been analysed.

The blue compact felspar was discovered by Widenmann at Krieglach in Stiria, forming a granitic mass with white quartz and silvery white somewhat unctuous plates, which have been considered by some mineralogists as mica, by others as talc. The green varieties occur in green porphyry and grunstein.

IV. Continuous Felspar, Kirw.

Its colour is reddish-grey or flesh-coloured, or pale reddish yellow, or olive green. It occurs in mass and generally contains hornblende or common crystallized felspar dispersed through it in various proportions. It is sometimes dull but generally possesses a feeble glimmering lustre: it is translucent at the edges: its fracture is fine-splintery passing into uneven earthy; its fragments are indeterminately angular. Its hardness is fully equal to that of common felspar and it is less brittle.

It melts at a high heat into a porous porcelain mass. It appears to be nearly connected with transition grunstein, and probably forms the basis of some of those porphyries which are commonly ranked as hornstone porphyries: indeed certain varieties of this and splintery hornstone resemble each other so closely in their external characters that it is by no means easy to ascertain to which species they belong. Hornstone however is in general both harder and tougher, and is infusible *per se* before the blowpipe, whereas continuous felspar is fusible, though it often requires for this purpose a very high and long continued heat.

V. Labradore Felspar. *Labradorstein*, Wern. *Feldspath opalin*, Hauy.

The proper colour of this mineral is smoak-grey or dark ash colour, but on account of the small crevices between the lamellæ of which it is composed, it presents a most beautiful play of vivid tints varying according to the position in which it is viewed: of blue it exhibits all the varieties from violet to smalt-blue; of green it displays the pure emerald green and various other tinges approaching to blue on one hand and yellow on the other; of yellow the usual shades are gold and lemon yellow verging into deep orange and thence into rich copper-red and tombac brown. The parts exhibiting these beautiful colours are disposed in irregular spots and patches, and the same spot if held in different positions displays various tints. It has hitherto been found only in detached rolled fragments. Internally it is shining passing into splintery, with a lustre between pearly and vitreous. Its principal fracture is perfectly lamellar in two directions, the lamellæ crossing each other at right angles; its cross fracture is somewhat conchoidal: it breaks into rhomboidal fragments with four specular faces. It usually exhibits large granular and sometimes though rarely strait lamellar, distinct concretions. It is strongly transluscent passing into semi-transparent. Sp. gr. 2.6 to 2.7.

It is fusible without addition before the blowpipe into a white enamel.

The only analysis that has yet been made of this mineral is by Bindheim, according to whom it contains

Silex - - - - -	69.5
Alumine - - - -	13.6
Sulphated lime - -	12.
Oxyd of copper -	0.7
Ditto of iron - -	0.3
	96.1
Loss - -	3.9
	100.0

It was first discovered by the Moravian missionaries on the Island of St. Paul on the coast of Labrador, and has since been found in Ingermannland in Norway, and in the vicinity of Lake Baikal in Siberia. It is sometimes accompanied by mica, black schorl and iron pyrites.

It is in considerable estimation on account of its beautiful colours for ornamental purposes.

On comparing the results of the analysis of felspar by Vauquelin and Chenevix, both of them chemists of acknowledged ability and scrupulous accuracy, it is impossible not to be struck with surprize at the remarkable difference which appears between them. That potash should appear in one analysis and not in the other is no extraordinary circumstance, because without a particular examination for this very object the potash would remain undetected and its amount would be transferred to the general account of loss: the loss therefore in Mr. Chenevix's analysis ought to be equal both to the loss and potash in Vauquelin's; but the amount set down as loss in both cases is nearly equal, therefore the difference between the earthy and metallic products of the two analyses amounts to 13 per cent. being the proportion of potash as ascertained by Vauquelin. In order to obtain some clue by which to account for this difference, the methods of analysis pursued by these chemists have been compared and examined, but without obtaining much satisfaction.

Mr. Chenevix[b] after finely pulverizing the felspar, treated it with caustic potash in a silver crucible, and the whole was then brought to a limpid solution by muriatic acid. 1. The liquor was evaporated to dryness and the saline residue digested in a slight excess of muriatic acid, a white powder remained insoluble which was silex. 2. The muriatic liquor with the washings of the silex was then mixed with ammonia, and a copious precipitate was thus obtained. 3. This precipitate was then dissolved in muriatic acid, and afterwards boiled with an excess of potash by which the iron was deposited; and the addition of muriat of ammonia then threw down the alumine. 4. The ammoniacal liquor No. 2, was treated with carbonat of potash, by which carbonat of lime was procured. This method of analysis appears quite unexceptionable as far as the earthy and metallic contents are concerned, and, if carefully performed, there appears no reason why its results should not be considered as giving the true proportions and quantities of the earths and oxyd of iron contained in felspar, proper allowance being first

[b] Phil. Trans. for 1802 p. 333.

made for the inevitable errors to which the moſt accurate analyſis is neceſſarily ſubject.

The method employed by Vauquelin was the following.[c] Having fuſed the felſpar with cauſtic potaſh, he diſſolved the maſs in dilute muriatic acid, and evaporated the whole to dryneſs: 1. the ſaline reſidue being drenched with water and filtered, the ſilex remained behind as a white inſoluble powder. 2. The clear liquor being treated with ammonia produced a copious white precipitate. 3. This precipitate was digeſted in cauſtic potaſh and left behind the iron: muriatic acid was then added to ſaturation, and afterwards carbonat of potaſh threw down the alumine. 4. The liquor No. 2, gave no precipitate with carbonated potaſh or ſulphuric acid, but oxalic acid occaſioned a precipitate of oxalat of lime, which when calcined, was conſidered as carbonat of lime, whence the amount of the lime was eſtimated according to the uſual proportions. The only exceptionable part of this analyſis relates to the method of procuring the lime, and this on two accounts: in the firſt place, oxalic acid would not ſeparate the whole of the lime from the liquor, which conſiſted of the muriats of lime, potaſh, and ammonia; and in the ſecond place, the oxalat of lime which was precipitated ought by no means, after having undergone calcination, to be conſidered as carbonat of lime, but as lime in a ſemi-cauſtic ſtate. It is further a ſingular circumſtance and contrary to general experience, that carbonat of potaſh ſhould have been unable to throw down the lime from the ſolution which was decompoſable by oxalic acid. But even if we allow the utmoſt poſſible weight to theſe objections, and in conſequence raiſe the amount of lime in Vauquelin's analyſis to an equality with that of Chenevix's, there ſtill remains a difference of 11 per cent. unnaccounted for. That potaſh is really contained in the Siberian felſpar appears alſo from a ſubſequent analyſis by Vauquelin, in which he uſed cauſtic ſoda as the primary ſolvent, and afterwards obtained cryſtals of alum by the addition of ſulphuric acid. It is however worthy of notice that the account of Vauquelin's experiments is not written by this eminent chemiſt himſelf, but is contained in a paper read at the *Societé philomathique* by Le Lievre, and in conſequence is not in the moſt authentic form.

With regard to the oppoſite analyſes of adularia by the above mentioned chemiſts, it is difficult to form any ſatisfactory opinion, as the details of Vauquelin's analyſis are not publiſhed. It may however be remarked that in the amount of ſilex they exactly correſpond, and that the proportion of alumine as determined by Vauquelin, approaches much nearer to the ſtatement of Chenevix than in the former inſtance. The chief difference is the proportion of lime, but if, as is probable, the ſame method was uſed by Vauquelin on this occaſion as was practiſed by him on the former one, it may be ſuſpected that Mr. Chenevix's eſtimate approaches nearer to the truth. The water of cryſtallization amounting to 1.75 according to Chenevix, is wholly neglected by Vauquelin; and it is obvious that the proportion of potaſh as given by this chemiſt is from mere eſtimation, and is reckoned at 14. becauſe juſt ſo much was wanted to compleat the original 100 parts that he operated on. The iron obtained by Chenevix is perhaps only a caſual ingredient of adularia: ſo that making the requiſite allowances for each analyſis, the quantity of potaſh can hardly be eſtimated at more than 6 per cent. It is however greatly to be wiſhed that Klaproth or Hatchett would undertake anew the full analyſis of this important mineral in all its varieties and ſubſpecies.

Some further intereſting particulars reſpecting felſpar are contained in a memoir by M. Gerhard.[d] Common felſpar when heated to incandeſcence loſes 1 *per cent.* (probably water). After being calcined it is readily acted on by ſulphuric acid, and the product is a little ſelenite and much alum; the ſilex remaining unaltered by the acid. From an analyſis conducted in this manner M. Gerhard ſtates the conſtituent parts of felſpar at

Silex -	64.
Lime -	6
Alumine	30
	100

Here it is worthy of remark that the preſence of potaſh in this mineral is fully aſcertained by the copious production of alum when it is treated after calcination with ſulphuric acid, and this is the leſs liable to ſuſpicion as the memoir was publiſhed long before the neceſſity of potaſh to the cryſtallization of alum was ſuſpected; in conſequence of which we find in Mr. G's analyſis no mention of potaſh, and perhaps it is ſomewhat in favour of the reduction which we have made in the proportion of alkali as given by Vauquelin, that this reduced proportion, viz. 6 *per cent.* added to the quan-

[c] Journ. des Mines, No. 49. p. 24. [d] Nouveaux Memoires de l'Acad. Roy. de Berlin, for 1783. p. 119.

tity of alumine found in common felſpar by Chenevix, viz. 24 *per cent.* exactly correſponds with the amount of alumine as ſtated by Gerhard. In the proportion of ſilex he alſo agrees preciſely with Chenevix, and in the quantity of lime differs only in the ratio of 6.25 to 6.

Common felſpar incloſed in a crucible and expoſed to a full melting heat, is converted to a milk-white ſemi-tranſparent maſs reſembling quartz. The addition of ſilex diminiſhes its fuſibility and renders the maſs more opake. Four parts of felſpar and one of chalk form a clear tranſparent glaſs of a ſlight yellowiſh green colour: but a much more beautiful glaſs may be obtained by calcining ſeparately one part of ſand, four of felſpar, and two of chalk, and then fuſing them together; this glaſs is however harder and more difficult to anneal than common glaſs, and the metallic oxyds only communicate to it dull muddy tinges of red and brown, except cobalt, which gives it a purer blue than common glaſs is capable of acquiring.

FERMENTATION *(Vinous) die Weinichte Gahrung.* Germ.

The important proceſs whereby ſaccharine ſolutions are converted into intoxicating liquors, capable of yielding alcohol by diſtillation, is one of the moſt complicated in chemiſtry, and the exact cauſe of this change is ſtill but very imperfectly known. We ſhall therefore content ourſelves in this place with noticing the principal requiſites to fermentation, the circumſtances that occur during the proceſs, and the eſſential product, referring to the articles SPIRITS *diſtilled*, MALT-LIQUORS, and WINE, ſome further particulars concerning theſe proceſſes.

The only ſubſtances which we know to be unqueſtionably requiſite to form a fermentable liquor are *Sugar* and *Water*. No vegetable juice will ferment that is not ſenſibly ſweet, or from which a portion of ſugar may not be extracted by chemical means; the ſtrength of vinous liquors is (other things being the ſame) in direct proportion to the quantity of ſugar contained before fermentation; the addition of ſugar to the weakly fermentable juices will enable them to produce a ſtrong full-bodied liquor, and the very eſſence of this proceſs is the diſappearance of ſugar and the conſequent production of alcohol.

With regard to the *water* it does not appear how far this is an active ingredient in vinous fermentation, but it is fully aſcertained that a certain degree of dilution is neceſſary to this proceſs; this degree exiſts naturally in the juice of grapes, the ſaccharine ſap of many trees, and other liquors ſpontaneouſly fermentable, and if theſe very liquors be deprived merely of great part of their water by gentle evaporation, they will not ferment till this is reſtored to them. On the other hand a ſaccharine juice may eaſily be too dilute, and then the fermentation is languid and imperfect.

But pure ſugar and water alone will not ferment, and therefore ſome other ſubſtance is alſo requiſite. Chemiſts have directed their attention largely to this point, but hitherto with little ſucceſs, nor is it at all certain or rendered probable that this other ſubſtance muſt be any individual principle, or whether there are not ſeveral which will ſerve equally well towards the decompoſition of the ſugar. Muſt, or grape juice, contains, beſides ſugar and water, a quantity of vegetable acid, chiefly the tartareous, and one or more ſubſtances obſcurely deſcribed under the name *extractive* or *mucilaginous*. Each of theſe is alſo requiſite to its fermentation, for if either is abſtracted the proceſs will not take place. But the tartareous acid is compoſed of that which gives the acid property, together with hydrogen, carbon, and other ingredients alſo common to the mucilaginous extract. This latter can only be defined to be a ſubſtance highly ſoluble in water, giving it a certain degree of tenacity and denſity, remaining as a viſcous jelly after ſlow evaporation to dryneſs, again ſoluble in water, moſt readily entering into ſpontaneous change at a moderate temperature, and giving by deſtructive diſtillation a number of gaſſeous products which indicate the preſence of carbon, hydrogen, oxygen, and in very ſmall portions, azot. But in the preſent ſtate of chemical knowledge little progreſs is made towards a ſatisfactory explanation of this proceſs by conſidering the *ultimate* analyſis of the fermentable materials, and at preſent we muſt ſatify ourſelves with their immediate compoſition.

It appears therefore from the example of grape juice, that at leaſt four ſubſtances are requiſite to fermentation, namely, ſugar, water, an acid, and what (for want of clearer definition) may be termed extractive matter, and when theſe ſimply remain together for a ſhort time in a moderately warm temperature they will be converted to a vinous liquor. The two latter ſubſtances we ſhall preſently return to when the other requiſites and circumſtances of the proceſs have been deſcribed.

A warm external temperature is alſo neceſſary to fermentation. This varies according to the natural fermentability of the materials and

their bulk. Thus grape-juice will readily begin to ferment at about 60°, and the proceſs is ſtrong and vehement at 70 or 80. The ſugar cane juice is ſo exceſſively prone to fermentation, that in the climate of the Weſt Indies the proceſs would begin in from ten to fifteen minutes, and hence as fermentation is the deſtruction of ſugar, it is neceſſary in the making of the ſugar, to begin the operations on the cane-juice immediately after it is preſſed on the plant. This operation begins with bringing it to a ſcalding heat, which immediately ſtops all tendency to fermentation. On the other hand no juice, however in itſelf fermentable, will ferment at a freezing temperature, ſo that all domeſtic proceſſes of the kind are performed within doors or near a fire, and in the large way chilling muſt equally be avoided. But as fermentation is attended with the production of heat, the liquor within the veſſel being always ſeveral degrees warmer than the outer air, large maſſes are of courſe leſs affected by the external cold and will ferment at a lower temperature.

The firſt ſigns of fermentation are a gentle inteſtine motion, the riſing of ſmall bubbles to the top of the liquor, and a whitiſh turbid appearance. This is ſoon followed by the collection of a froth or head, conſiſting of an infinite number of air-bubbles entangled in the liquor, which as the proceſs advances riſe ſlowly to a conſiderable height, forming a white denſe permanent froth. A very large portion of the gas alſo eſcapes, which has always a ſtrong agreeable penetrating vinous ſmell. The temperature of the liquor at the ſame time increaſes ſeveral degrees above the external air, and continues ſo during the whole of the proceſs. Sooner or later theſe appearances gradually ſubſide, the head of foam ſettles into a denſe froth, and on turning it aſide the liquor beneath appears much clearer, and nearly at reſt, having depoſited a copious ſediment, and from being clammy and ſaccharine to the taſte it is now vinous, and intoxicating, thinner and of leſs ſpecific gravity.

The proceſs however does not ſtop ſuddenly, but goes off very gradually, the liquor continuing to *work* or throw up foam, to clarify, to attenuate, to encreaſe in intoxicating power, and more compleatly to loſe all its ſugar, which at laſt can now no longer be diſcerned by the taſte, or detected by chemical analyſis. The vinous liquor when compleat, if of ſufficient ſtrength and well fermented, will now keep for an indefinite time in veſſels ſecured from air, and undergoes comparatively little further alteration except in becoming more perfectly limpid by the depoſition of an additional quantity of ſediment.

The nature of the gas of fermenting liquors has long been known to conſiſt for the moſt part of carbonic acid, and therefore it will extinguiſh candles, deſtroy animal life, convert alkalies into alkaline carbonats, and the like. But it is not ſimply carbonic acid that is given off, for it has been found by Scheele to hold in ſolution a ſenſible portion of alcohol, and by Prouſt to contain a quantity of azot. Mr. Collier has alſo found[a] that the gas contains all the materials requiſite for vinous fermentation. For this, he paſſed the whole gas from a ninety gallon fermenting tun through a caſk of water, and divided the water thus impregnated into three parts, the firſt of which was immediately diſtilled and gave a ſmall quantity of ſpirit, to the ſecond was added ſome yeaſt by which a new fermentation was excited and the ſubſequent product of diſtilled ſpirit was almoſt doubled, and the third being ſuffered to remain longer produced ſome vinegar.

The attenuation of liquors by fermentation or the diminution of their ſpecific gravity, is very ſtriking. This is commonly ſeen by the hydrometer, which ſwims much deeper in fermented liquor than in the ſame materials before fermentation. Moſt of this attenuation is doubtleſs owing both to the deſtruction of the ſugar, which diſſolved in water adds to its denſity, and to the conſequent production of alcohol, which on the contrary by mixture with water leſſens its denſity. The extract or mucilage alſo appears to be in ſome degree deſtroyed by fermentation, for the gelatinous conſiſtence of thick liquors is much leſſened thereby, though this quality as far as it depends on mucilaginous extract is not ſo completely loſt as the ſaccharine material, many of the full-bodied ales for example, retaining much of their original clamminеſs and gelatinous denſity.

It has been doubted whether alcohol exiſts ready formed in vinous liquors, or whether it is not then in ſome intermediate ſtate, and is brought to a perfect ſpirit by the boiling heat required for diſtillation. It is not eaſy to deviſe any unexceptionable mode of determining this queſtion. Fabbroni argues in favour of alcohol being a *product* and not an *educt* from wine, that wine cannot be again formed by adding the diſtilled alcohol to the reſidue; and alſo that if a ſmall portion of alcohol is added to wine, it

[a] Manch. Mem. vol. 5.

may be ſeparated again almoſt entirely by carbonat of potaſh (with which alcohol will not unite), but this ſalt will not ſeparate any alcohol from wine in its natural ſtate. This laſt fact however only ſhews that the union of the alcoholic with the other part of the wine is too ſtrong to be broken by ſimple affinity without the aſſiſtance of heat; and as to the former, it is highly probable that the boiling heat operates ſome change on the other conſtituents of wine, the effect of which can never be done away by the mere return of the ſpirit which has been driven off. This opinion therefore though by no means improbable, wants further confirmation.

Alcohol is not immediately formed in fermenting liquors, as it does not appear till the fermentation is compleat, for the liquor diſtilled in the early ſtage of the proceſs will not yield a drop of ſpirit.

The external air ſeems to have no chemical effect whatever in the proceſs of vinous fermentation, as it may be conducted full as well in cloſe as in open veſſels, always allowing room however for the great expanſion of the materials and the vaſt production of gas. Mr. Collier has alſo found by direct experiment that more ſpirit is produced by cloſe than by open fermentation. In three ſeparate experiments, in each of which equal quantities of wort and yeaſt were fermented under circumſtances preciſely ſimilar, with the ſingle exception that in one the veſſel was open and in the other it was cloſed (having no exit but through a tube dipping in water) he found that on diſtilling each fermented liquor and obtaining the ſame quantity of ſpirit from each, that belonging to the cloſe-fermenting veſſels was conſtantly of a leſs ſpecific gravity, and conſequently contained more alcohol than the other. Where the ſpirit from the open veſſel was 74 degrees below proof, that from the cloſed veſſel was 56: where the former was 83, the latter was 65; and where 103, the other was 93.

The theory of vinous fermentation is ſtill involved in extreme difficulty, on account of the very compound nature of all the ſubſtances employed in it, and their great tendency to decompoſition in a variety of methods.

The reſults of the experiments of Lavoiſier ſhould not paſs unnoticed, though it is obvious that much too great ſimplicity is attempted in the explanation of a proceſs which every circumſtance ſhows to be very complicated. It is ſome advantage however that the action of the external air ſo neceſſary to be conſidered in moſt decompoſitions of vegetable matter may here be entirely put out of the queſtion. The ſimple point to which Lavoiſier's experiments tend is (ſetting aſide all other agents) to explain how ſugar becomes converted into carbonic acid and alcohol, which after all, is the great phenomenon of vinous fermentation. The entire products of ſugar, yeaſt, and water fermented in cloſe veſſels, are ſtated to be carbonic acid, alcohol, and water, chiefly, together with a ſmall quantity of acetous acid and part of the materials undecompoſed. We ſhall not enumerate the exact compoſition given by this eminent chemiſt of all the ingredients and products of fermentation, nor enlarge on the many ſources of inaccuracy which may be pointed out, but the theory ſuggeſted by the author from theſe experiments is the following. Sugar is a compound of about 8 of hydrogen, 64 of oxygen, and 28 of carbon, and the proceſs of fermentation effects a change merely in the arrangement of the conſtituent parts of the ſugar, converting one portion into carbonic acid and the other into alcohol: and hence as the carbonic acid contains only carbon with a large proportion of oxygen, the portion which is left muſt contain all the hydrogen, now concentrated into a much ſmaller compaſs, part of the carbon, and only the ſmall remaining portion of oxygen. Or in other words, by this new arrangement of the ingredients of the ſugar, one portion (namely the carbonic acid) is totally deprived of hydrogen and overloaded with oxygen, and conſequently the other portion (which is the alcohol) abounds in hydrogen and is deficient in oxygen. The carbon is nearly equally divided between the two products relatively to their quantity.

Perhaps no more plauſible theory has yet been offered of the general phenomenon of vinous fermentation, though it is ſo extremely defective in eſſential parts, and even not correſponding with the alledged compoſition of alcohol given by the ſame chemiſt in another part of his enquiries, that it can only be regarded as an ingenious and happy conjecture.

The great queſtion ſtill remains for future enquirers to determine: what is it that cauſes ſugar to ferment; for it has been proved that ſugar will not of itſelf begin this ſpontaneous change into carbonic acid and alcohol, though when once begun, probably the proceſs will go on without further aſſiſtance. It has been already mentioned that both extractive matter and an acid are preſent in every known inſtance of vinous fermentation, and for any thing that appears to the contrary, both of them are neceſſary, though the requiſite quantity of each is

very ſmall compared to the ſugar; therefore the ſtrength or body of the fermented liquor is in direct proportion to the quantity of ſugar alone, (the fermentation having been complete) and there is ſtrong reaſon to ſuppoſe that the extractive matter and the acid are only acceſſary ingredients but ſtill eſſential, or thoſe without which the vinous decompoſition of ſugar cannot be effected.

It has been ſuppoſed that it is the *vegeto-animal* extract as it has been called, which exiſts in the fermentible juices of vegetables that cauſes the firſt change in the ſugar. The preciſe nature of this vegeto-animal matter is not very well known, it may be ſuppoſed to be ſimilar to the gluten of wheat, but moſt intimately combined with the vegetable ſaccharine mucilage, and hence extremely ſuſceptible of ſpontaneous change. The chief if not the only proof of its exiſtence in many of theſe combinations is the production of a quantity of ammonia when decompoſed by heat, which alkali is almoſt uniformly *formed* by the action of fire, and indicates in the recent vegetable the exiſtence of azot. It may therefore be more properly termed the azotic than the vegeto-animal ingredient, and as mentioned under the article BREAD, it ſeems to be peculiarly requiſite to the panary fermentation, and to perform the moſt important part in this proceſs.

Some of the commoneſt fermenting materials ſuch as wort of malt, or the infuſion of the ſoluble part of barley rendered ſaccharine by previous decompoſition, it is well known will hardly enter into fermentation without the addition of *yeaſt*, and hence chemiſts have ſought in this ſubſtance for the principle which gives the firſt impulſe to the fermentation of ſugar. The analyſis of yeaſt[b] preſents a vaſt variety of ingredients, the chief of which are the carbonic, acetic, and malic acids, mucilage, ſugar, and *gluten*. Of theſe the latter is in the largeſt proportion, which would ſeem to give much weight to the opinion of the great ſhare which the azotic ingredient has in inducing fermentation.

Yet Mr. Henry[c] found by a ſeries of very intereſting experiments that malt infuſion might be made to enter into complete fermentation ſimply by impregnating it with carbonic acid from chalk and ſulphuric acid, and the liquor thus fermented gave a yeaſt, which made perfect bread, gave alcohol by diſtillation, and vinegar by further keeping. Undoubtedly the wort itſelf contained all the ingredients of yeaſt ſince this ſubſtance was produced during the fermentation, but the experiment is deciſive to prove that no addition of azotic extract is required to begin fermentation in materials naturally fermentible, though when once begun, the yeaſt as faſt as it was produced muſt have aſſiſted in the fermentation then going on.

The evidence for the neceſſity of an acid to begin fermentation is therefore more deciſive, but it ſtill is doubtful what particular acid is required, or whether ſeveral will anſwer the purpoſe.

In Mr. Henry's experiments the acid was the carbonic, and from the arrangement of the apparatus probably a ſmall portion of the ſulphuric was alſo carried in along with it. But in grape juice no evidence can be given of the exiſtence of the carbonic acid ready formed, though the tartaric, and malic, and other vegetable acids contain within themſelves the two ingredients of carbonic acid, and it is well known that they are chiefly and ultimately reſolvable into the carbonic. Yeaſt will even induce fermentation after it is preſſed and dried into ſolid cakes, (a practice not uncommon as it will keep a great length of time in this form) but after this operation it can hardly contain an atom of carbonic acid ready formed, though with abundant tendency to produce it by the firſt mutual action of its other conſtituent parts.

Many intereſting enquiries therefore remain to be carried on, before we can have a full and ſatisfactory theory of this moſt important proceſs of vinous fermentation.

FERMENTATION, *(Acetous)*. See ACETOUS ACID and VINEGAR.

FERMENTATION *(Putrid)*. See PUTREFACTION.

FERNAMBOUC WOOD. See BRAZIL WOOD.

FERRILITE. See BASALT.

FEUERSTEIN. See FLINT.

FIBRE OF PLANTS. Almoſt all plants contain a fibrous matter, which is diſtinguiſhed by its comparative inſolubility in all chemical agents, indeſtructibility by ſpontaneous change, and by a certain toughneſs and elaſticity produced by the ſtrong intertexture of minute fibres. Theſe fibres are ſometimes highly flexible and firm, as the ſtringy ſtalk of the hemp plant, the aloe, the bark of the birch, and other trees that afford all the varieties of matting; with greater hardneſs and brittleneſs they exiſt in the cane, but ſtill highly flexible and elaſtic; and with ſtill greater denſity and diminiſhed flexibility

[b] Weſtrumb. Thomſon's Chem. Vol. 4. [c] Mancheſter. Mem. Vol. 1.

they form the ligneous fibre or wood of the larger trees. The chemical analyſis of vegetable fibre, which preſents a greater proportion of carbon and earthy matter than any other vegetable ſubſtance will be deſcribed under the article Wood.

FIBRIN (Animal), MUSCULAR FIBRE or FLESH.

The muſcle or fleſh of animals, a ſubſtance equally important in the ſtudy of phyſiology as of animal chemiſtry, is compoſed of an infinite number of oblong or cylindrical, ſoft, nearly inelaſtic, ſemitranſparent, generally ſomewhat red fibres, which examined microſcopically are ſeen to ſubdivide, as far as the power of glaſſes will carry the eye, into bundles of fibrils parallel to each other, and bound together by minute cellular web of obviouſly a different nature. The circumſtance which in a phyſiological point of view peculiarly diſtinguiſhes muſcular fibre from every ſubſtance in nature is its diſpoſition, when living, to contract in length on the application of ſtimuli, and to return immediately to a ſtate of relaxation, an inherent power totally independent of any known mechanical laws of motion, and a grand phenomenon of animal life.

When fibre is chemically examined it muſt be remembered that the living muſcle, beſides being interſected to extreme minuteneſs with cellular web, is penetrated by arteries, veins, nervous fibrils, and lymphatics, all of which, with their contents, muſt be more or leſs mingled with the proper fibre, and therefore the chemical analyſis of pure fibre cannot be preciſely aſcertained. However, maceration with water and mechanical preſſure will remove much of this extraneous matter, and in this ſtate we muſt at preſent conſider it.

Fibrin, it may be premiſed, has ſo cloſe a reſemblance with the gluten or coagulum of Blood, that in a chemical point of view theſe ſubſtances are nearly identical.

When a portion of muſcle cut into thin ſhreds is macerated in cold water for ſeveral hours, the water becomes red by the extraction of the blood and extraneous parts combined with the animal fibre, which laſt gradually becomes whiter and cleaner. This maceration ſhould be aſſiſted by frequent preſſure, and by often changing the water it may be continued ſeveral days without putreſcency in the fibre itſelf. If the fleſh is then boiled long in water ſome more animal fluids are extracted, chiefly gelatin, together with coagulated flocculi of albumen as Fourcroy has obſerved, and ſome drops of oil. When the ſoluble parts of fibre are wanted for domeſtic purpoſes, as for broths, ſoups, &c. the previous maceration in cold water is omitted. The fibre after the action of cold and hot water is exhauſted, remains a grey white inſipid ſtringy ſubſtance, which rather hardens by the further continuance in hot water, and when dried ſlowly in a warm air becomes ſemitranſparent like horn and very brittle. This is fibrin in the pureſt ſtate in which it can be procured.

Fibrin thus prepared is totally inſoluble in water. It diſſolves readily in moſt of the acids, but with the dilute nitric it gives out a large portion of azotic gas of great purity. A ſtronger nitric acid produces a more complicated effect, and, as Berthollet has obſerved in his valuable Memoir on Animal Matters, converts part of it into a kind of ſuetty fat which collects on the ſurface, whilſt another portion is changed by means of the nitric acid into the oxalic, which therefore is always found in the remaining liquor.

Fibre added to the fixed alkalies gives off ſome ammonia, and is reduced to a kind of ſoap by union with the alkali.

Mr. Hatchett's valuable experiments[a] on this ſubſtance throw great light on the conſtitution of muſcular fibre, and point out a moſt ſtriking reſemblance to condenſed albumen in a variety of particulars before unnoticed. They are chiefly the following. Muſcular fibre (previouſly exhauſted by long maceration in cold and hot water of every thing ſoluble in that fluid) was ſteeped for a fortnight in nitric acid diluted with three parts of water. The acid acquired a yellow tinge and had acquired all the properties of the nitric ſolution of *albumen*. The chief part of the fibre thus thoroughly penetrated by the acid was then put into boiling water, in which it diſſolved and gave a gelatinous maſs by evaporation, which, when rediſſolved in water, was precipitated by infuſion of tan and by nitro-muriat of tin, in the preciſe manner of all the common albuminous ſolutions. The fibre after ſteeping in the acid was chiefly diſſolved in ammonia, forming a brown orange ſolution. With potaſh ammonia was extricated, and it formed a ſoap like the albuminous ſoaps. The reſidue left undiſſolved after the action of ammonia conſiſted chiefly of fat. But when the waſhed fibre was treated with *boiling* nitric acid, the ſolution ſtill more cloſely reſembled that of albumen in nitric acid, but with this

[a] Phil. Trans. vol. 90.

additional circumſtance, that on ſuperſaturation with ammonia a copious white precipitate fell down, which conſiſted of the phoſphat and oxalat of lime, of which the former preexiſted in the fibre, and the oxalic acid of the latter was *formed* by the action of the nitric acid on ſome portion, probably the gelatinous, of the fibre, and then united with the carbonat of lime which is alſo preſent.

The ſolution if made by *boiling* nitric acid alſo contains a notable exceſs of oxalic acid as well as oxalat of lime, but this acid is not found in any ſtate when only *cold* nitric acid has been uſed, and hence the oxalic acid is obviouſly a product and is not to be conſidered as a conſtituent of muſcular fibre.

The liquor or broth of fibre boiled in water contains, beſides gelatin and other animal juices, a quantity of phoſphat of ſoda and even phoſphat of lime, which is almoſt entirely extracted from the fibre by long boiling.

Lime therefore is found in muſcular fibre in two ſtates, as a phoſphat which is chiefly ſeparable by long boiling, and in ſome other ſtate in which it is not extracted by water but remains ready to combine with the oxalic acid as ſoon as formed, for this acid will not decompoſe the phoſphat. This other ſtate therefore is probably the carbonat, and the quantity of lime in this combination is ſufficient to form 17 grains of the dry oxalat from 200 grains of the muſcle previouſly exhauſted by water and dried, and then diſſolved in boiling nitric acid and precipitated by ammonia.

Much difference appears in the quantity of earthy ſalts in muſcular fibre in proportion to the age of the animal. Thus Mr. Hatchett found that though beef contained both phoſphat and carbonat of lime, veal gave hardly any indications of the latter and a much ſmaller quantity of the phoſphat, a circumſtance of ſome importance in phyſiology.

The analyſis by fire ſhewed the following very notable difference between the three great conſtituents of the ſoft parts of animals, namely gelatin, albumen, and fibrin, in the proportion both of carbon and of earthy reſidue.

Five hundred grains of iſinglaſs (the pureſt ſpecimen of gelatin that can be taken) diſtilled with a ſtrong heat in cloſe veſſels left 56 grains of reſidue, of which 54.5 were loſt by open calcination and therefore were carbon, and the reſidue, amounting to 1.5, appeared to be phoſphat of ſoda with a trace of phoſphat of lime.

Five hundred grains of dry albumen treated in the ſame way gave 63.25 grains of carbon and 11.25 of reſiduum, chiefly ſoda, rendered cauſtic by the heat, together with phoſphat of ſoda and a very ſmall portion of phoſphat of lime.

Five hundred grains of dry prepared muſcle of beef gave 82.4 of carbon and 25.6 of reſidue, the greateſt part of which was carbonat of lime mixed with ſome pure lime and a little of the phoſphat. But ſtill more earthy ſalt is contained in muſcular fibre than appears in this eſtimate, as the muſcular fibre was previouſly exhauſted of every thing ſoluble in boiling water, under which, as already mentioned, is to be included almoſt all its natural content of phoſphat of lime.

The general inference from theſe experiments and others mentioned under the article ALBUMEN, is that (ſetting aſide the ſaline, earthy, and what may be conſidered as acceſſary ingredients of muſcular fibre derived from its intricate organization) the principal conſtituent is a ſubſtance which from the effect of the leading chemical reagents may be inferred to be nearly identical with inſpiſſated albumen, and this appears to be the primary ſubſtance of the organization of many if not moſt of the ſoft parts of the body in which the moſt important functions of life reſide.

A few miſcellaneous circumſtances may be added concerning muſcular fibre. When thoroughly waſhed and freed from all that water can extract, it does not readily putrefy, but in its natural ſtate it ſoon undergoes this change, the texture becomes flabby and looſe, the colour pale, and the ſmell exceſſively fetid. The fleſh of young animals (other things being the ſame) more readily putrefies than of old ones. When immerſed in running water, or buried under ground under particular circumſtances, it changes to that ſingular ſpermaceti-like matter which has been termed ADIPOCIRE. When muſcular fleſh is ſlowly and thoroughly dried and kept in a dry air, it will remain long without undergoing any change. Alcohol extracts the colour from muſcle, hardens its texture and effectually preſerves it from further change. In general almoſt all the antiſeptics are more efficacious in preſerving fibre from putrefaction than any other of the ſoft parts of the body.

Of the volatile products of the diſtillation of muſcular fibre ammonia is the moſt important, and indicates the exiſtence of much azot in the fibre itſelf. An acid is alſo given out, which is acrid, not cryſtallizable, and has the peculiar ſmell of roaſt meat. It was conſidered by Berthollet as an undeſcribed acid, and called by

him the *zoonic*, but it ſeems now generally allowed that it conſiſts chiefly of the acetous acid fouled and altered by ſome of the animal ſubſtances rendered empyreumatic by the heat uſed to procure it.

FILTRATION is one of the daily operations in chemiſtry, apparently ſimple and trivial, but concerning which a few uſeful particulars may be mentioned. *(See the Appendix, article Filter).*

FISH SOAP is a kind of ſoap lately attempted to be introduced in manufacture, made by diſſolving refuſe fiſh of all kinds in cauſtic alkali. (See SOAP.)

FIRE. See CALORIC.

FIRE DAMP is that inflammable gas generated in many mines, particularly coal pits, which often produces moſt dreadful exploſions when accidentally fired by the workmen. It is only to be prevented by thorough ventiliation.

FLESH. See FIBRIN.

FLINT.[a] *Feuerſtein.* Wern. *Pierre a fuſil.* Broch. *Quartz-agathe pyromaque.* Hauy.

The colour of this mineral is ſmoak-grey of different ſhades, paſſing into greyiſh-black and almoſt perfect black, or yellowiſh-grey paſſing into yellowiſh-white, wine and ochre yellow; it alſo occurs bluiſh-grey, yellowiſh and reddiſh-brown. Two or more colours are often found in the ſame ſpecimen forming points, ſpots, clouds, or ſtripes. It generally alſo exhibits opake white ſpots. It occurs in maſs, diſſeminated, in angular grains and fragments, in globular and tubercular maſſes, or carious, and amorphous, ſometimes alſo in pſeudo-cryſtals either pyramidal or priſmatic moulded on calcareous ſpar. It alſo conſtitutes the ſubſtance of various petrifactions as echinites and coralloids. Its external luſtre is caſual, internally it is glimmering. Its fracture is perfectly conchoidal: it breaks into indeterminately angular and very ſharp-edged fragments. It ſometimes though rarely occurs in lamellar diſtinct concretions. It is tranſlucent, varying in degree according to the depth of colour, the very light-grey varieties being ſemi-tranſparent. Its hardneſs is a little greater than that of quartz, it is eaſily frangible in any direction. Sp. gr. 2.58 to 2.59.

When expoſed to the blow-pipe it becomes of an opake-white, but is wholly infuſible without addition. By being heated red hot in a diſtillatory apparatus it yields from one to two per cent. of a ſomewhat empyreumatic water and a little carbonic acid. If projected on fuſed nitre, it gives out a few ſparks accompanied by a ſlight detonation. It has been analyſed by Klaproth[b] and Vauquelin,[c] with the following reſults.

	Klap.		Vauq.
Silex - -	98.	—	97.
Lime - -	0.5	—	0.
Alumine -	0.25 }		1.
Oxyd of Iron	0.28 }		
Loſs - - -	1.	—	2.
	100		100

The cloudy and opake greyiſh ſpecks which frequently occur in this mineral contain according to Vauquelin, from two to five per cent. of carbonated lime, and the white opake cruſt with which thoſe ſpecimens are covered that are taken immediately out of chalk, conſiſts according to the ſame able chemiſt of

Silex - - - -	86.42
Oxyd of iron - -	1.23
Carbonated Lime	9.88
Loſs - - - -	2.47
	100 ..

Flint occurs ſometimes though rarely in primitive rocks forming veins, but when belonging to this formation its fracture has a tendency to ſplintery, and is leſs eaſily frangible than common flint, and in fact appears to be a variety of hornſtone paſſing into chalcedony. Common flint occurs in rounded pebbles conſtituting the greater part of the extenſive beds of gravel which accompany the ranges of chalk-hills, but here it is evidently worn by attrition and diſpoſed in a fortuitous irregular manner. It is only in the chalk-hills themſelves that it appears in its native repoſitory: here it is diſpoſed in regular beds alternating with the chalk; and detached maſſes are often enveloped in the chalk itſelf. A bed of flint is never a continuous ſtratum, but is compoſed of irregular flattened nodules with tubercular or long projecting proceſſes, each ſeparated from the other by ochery chalk, yet the whole bed preſerves its parallelifm very exactly. Many nodules are hollow, and if the cavity communicates with the outſide, are for the moſt part filled with chalk, but if there is no external aperture, the hollow is lined with minute pyramids of quartz or tubercles of chalcedony.

The formation of flint is a problem that has been diſcuſſed by the contending parties of Neptuniſts and Volcaniſts, but without coming to any ſatisfactory concluſion on either ſide:

[a] Brochant, Jameſon, Kirwan. [b] Analyt. Eſſ. I. p. 40. [c] Journ. des Mines No. 33. p. 702.

neither the infiltration of diſſolved nor the injection of melted ſilex, at all accounting for the regular manner in which the beds of flint are diſpoſed. Thus much is certain, that flints recently taken out of the quarry (not out of gravel beds) contain a much larger proportion of water than is indicated by their analyſis, which probably was performed on long-kept ſpecimens, ſince at every fracture the whole ſurface is covered over with minute drops of dew, which give a very ſenſible moiſture to the finger when rubbed over it. It alſo ſeems evident that the flints in chalk beds have formerly been in a ſoft ſtate, becauſe they are conſtantly found covered with a hard white coat, a line or more in thickneſs but not ſeparated from the reſt of the ſtone, which contains from 9 to 10 per cent. of lime.

Thoſe flints which burn to a pure white colour are employed in the finer kinds of pottery. The light-coloured flints are made into gun-flints, for which they are admirably qualified by the plenty and vivacity of the ſparks which they yield on colliſion with ſteel, and from the eaſe with which they are manufactured on account of their natural tendency to break into wedge-ſhaped fragments. Flint is alſo an excellent material in building; the irregularity of its ſurface affords numerous points of contact for the cement, and it appears unalterable under every viciſſitude of weather. Numerous beautiful ſpecimens of flint buildings occur in the counties of Eſſex, Suffolk, and Norfolk.

FLOETZ. See Rocks.

FLOWERS. *Blumen.* Germ.

The old chemiſts were accuſtomed to denote by this name ſeveral ſubſtances both metallic and otherwiſe, which were procured by ſublimation and were in the form of ſlightly cohering powder or ſpicular cryſtals. Thus we find mention made of flowers of antimony, arſenic, zinc and biſmuth, which are the ſublimed oxyds of theſe metals either pure or combined with a little ſulphur or muriatic acid; alſo of flowers of ſulphur, of benzoin and ſal ammoniac. The term is at preſent almoſt entirely fallen into diſuſe.

FLUOR[a]. *Chaux fluatée,* Hauy.

This ſpecies is divided into the two following ſubſpecies.

I. Fluor Spar; *Fluſs-ſpath,* Wern. *Spath fluor,* Broch. *Blue John,* of the Derbyſhire miners.

The colours exhibited by this mineral are very various; it is pearl or ſmoak-grey, yellowiſh-brown paſſing into browniſh-black; or reddiſh-white paſſing into roſe colour, (the falſe ruby of ſome authors); or violet blue (falſe amethyſt) paſſing into ſmalt, and ſky-blue (falſe ſapphire) and bluiſh-black; or greeniſh-white paſſing into apple-green, graſs and emerald-green (falſe emerald, *(prime d'emeraude)*; or wax and honey-yellow (falſe topaz). In the cryſtallized varieties the colours are for the moſt part uniform, but the maſſive variety diſplays ſeveral colours arranged in dots, clouds, and parallel waving or angular veins like the fortification agate. It occurs in maſs, diſſeminated, and cryſtallized. Its primitive figure is a regular octohedron compoſed of tetrahedral molecules: it alſo exhibits the following varieties.

1. The octohedron, the ſummits of which terminate in lines inſtead of points.
2. The cube.
3. The rhomboidal dodecahedron.
4. The octohedron, all the edges of which are replaced by ſecondary planes.
5. The cube modified in the ſame manner as the preceding variety. When this modification attains its limit the original faces of the cube diſappear, and are each replaced by a very broad four-ſided pyramid.
6. A ſolid exhibiting facets with four, ſix, and eight ſides, and produced from a combination of the octohedron with var. 2 & 3.
7. An imperfect octohedron with convex faces giving the whole a ſpheroidal appearance. The cryſtals are either ſingle or irregularly intermixed or accumulated upon one another forming rude priſms. Their ſize varies from very ſmall to very large. The ſurface of the cryſtals is either ſmooth and ſhining or rough and glimmering: the ſurfaces of the octohedron are generally rough. Its internal luſtre is brightly ſhining and vitreous, ſomewhat inclining to pearly. Its fracture is foliated in four directions; its fragments are for the moſt part tetrahedral. When in maſs it is tranſlucent; the cryſtals are generally tranſparent or ſemi-tranſparent. It occurs ſometimes in granular, rarely in lamellar diſtinct concretions. Its hardneſs is ſuperior to that of calcareous ſpar; it is brittle and eaſily frangible. Sp. gr. 3.1 to 3.2.

Fluor ſpar when expoſed without addition to the action of the blowpipe, crackles and decrepitates with conſiderable violence, and at length melts down into a greyiſh-white enamel. When laid on hot charcoal it gives out a bluiſh or greeniſh phoſphoric light, a ſimilar light is alſo produced by rubbing together two pieces in the

[a] Emmerling, Hauy, Brochant, Jameſon.

dark. Certain varieties of fluor are more phoſphoreſcent than others, but the moſt remarkable example of this phenomenon is a violet-coloured fluor found in Siberia, and ſold in Europe in ſmall pieces under the name of *chlorophane:* if this is laid on a hot coal it preſently is obſerved to glow with a moſt beautiful phoſphoreſcent light of an emerald colour; after each heating its violet colour is diminiſhed, and when it is become nearly colourleſs its phoſphoreſcence is exhauſted.

If ſulphuric acid is poured on very finely pulverized fluor ſpar, and a gentle heat is applied to the mixture, a peculiar gaſſeous acid is diſengaged which has obtained the name of the Fluoric.

Fluor ſpar has hitherto been only analyſed by Scheele, who ſtates it be a compound of

Lime - - -	57.
Fluoric acid -	16.
Water - -	27
	100

Beſides theſe which may be conſidered as the eſſential conſtituents of this mineral, the coloured varieties contain oxyd of iron and very often bitumen; this is particularly the caſe with the blue and black kinds; hence it is that blue fluor when laid for a time in warm aſhes, acquires an orange or bright ochre colour from the evaporation and decompoſition of its bitumen.

Fluor ſpar forms veins in primitive mountains accompanied by tin ore, mica, apatit, and quartz, as in Cornwall, and at Zinnwald in Bohemia; it alſo occurs in argillaceous ſchiſtus accompanied by ſpathoſe iron ore, quartz, calcareous ſpar and heavy ſpar, in Cumberland and Durham; alſo in ſecondary limeſtone filled with organic remains, accompanied by galena, blende, calcareous, pearl, and heavy ſpars, quartz, clay, and ſolid bitumen, in Derbyſhire. It is alſo met with in Aberdeenſhire, in Brittany in France, Chamouni in Switzerland, in Saxony, Swabia and the Hartz, in Germany, and in Norway and Sweden.

Fluor was formerly and ſtill continues to be uſed, as a very efficacious flux in the reduction of various metallic ores, whence it obtained its name: it is alſo the only ſubſtance from which fluoric acid is procured. The maſſive pieces when of ſufficient ſize, ſolidity, and beauty, are wrought into various extremely ornamental objects ſuch as vaſes, baſons, obeliſks, &c. This manufacture is entirely confined to Derbyſhire, no other part of the world affording fluor ſufficiently compact for this purpoſe. The fluor that is manufactured, commonly called *Derbyſhire ſpar*, is found only in one mine a little to the Weſt of Caſtleton; it here occurs in veins and detached maſſes from three inches to a foot in thickneſs. The method of manufacturing it is as follows.

"When the fluor is intended to be worked "into a vaſe or the like article, a piece is "ſelected fit for the purpoſe, and if after "minute examination it be found free from "defects, it is carved with a mallet and chiſſel "into a ſpherical form, and then fixed on a "chock with an exceedingly ſtrong cement. "The chock is then ſcrewed on the lathe, "a ſlow motion is produced and water con-"tinually drops on the ſtone to keep the tool "cold, which is at firſt applied with great care. "This tool is a piece of the beſt ſteel, about "two feet long and half an inch ſquare; it "is reduced to a point at each end, and tem-"pered to ſuit the work. As the ſurface "becomes ſmoother the tool is applied more "boldly and the motion much quickened, till "the piece of fluor be reduced to its intended "form.

"The piece being thus formed and rendered "ſmooth by the ſteel inſtruments, in order to "render it fit to receive a poliſh, a coarſe ſtone "is applied with water ſo long as the ſmoothneſs "is improved by theſe means, then finer grit-"ſtone, pumice, &c. till the piece be ſufficiently "ſmooth to receive coarſe emery, and after-"wards fine emery. If with the latter it "appear of a good ſhining gloſs, then the fineſt "putty is employed for a conſiderable length "of time, till the poliſh be as bright as poſſible, "which is known by throwing water on it. If "the part thus watered appear higher poliſhed "than the reſt the poliſhing is continued till "water will not heighten the appearance.

"The advantage of a lathe worked by water "is particularly conſpicuous in forming delicate "hollow vaſes, &c. for by the uſe of the foot-"lathe the fluor was frequently broken, and its "laminated texture at all times diſturbed, but "the uſe of the water-lathe by its ſteadineſs "prevents theſe inconveniences." [b]

II. COMPACT FLUOR. *Dichter. fluſs.* Wern. *Fluor compacte.* Broch.

Its colour is clear greeniſh-grey paſſing into verdegris and greeniſh-white; it is alſo occaſionally marked with yellowiſh and reddiſh-brown

[b] Mawe's Mineralogy of Derbyſhire, p. 79.

ſpots. It occurs in maſs. Externally it is dull or feebly glimmering; internally glimmering, with a vitreous luſtre. Its fracture is even, approaching on the one hand to imperfect and flat conchoidal, and on the other to ſplintery. It breaks into indeterminately angular and ſharp-edged fragments; it is tranſlucent; conſiderably harder than the preceding ſub-ſpecies; and eaſily frangible.

It occurs in veins with fluor ſpar at Stolberg in the Hartz, and in Derbyſhire, but is very rare.

FLUORIC ACID. *Acide Fluorique.* Fr. *Fluſſpathſaure.* Germ.

In the Tranſactions of the Academy of Sciences at Berlin for 1768, is contained a memoir by Margraaf on fluor ſpar. This able chemiſt found that when the above mineral was diſtilled with ſulphuric acid a volatile acid vapour was diſengaged which depoſited a white earth on coming into contact with water: he alſo remarked that the retort in which the diſtillation was carried on, was corroded and worn into holes by the proceſs. Three years after, Scheele publiſhed a valuable eſſay on the ſame ſubject, in which he proved that fluor ſpar conſiſted of lime combined with a peculiar acid, many of the properties of which were inveſtigated by him with great ſucceſs. Prieſtley then took up the ſubject, confining his attention for the moſt part to the action of fluoric acid in the ſtate of gas. Since the date of theſe laſt experiments but few additions have been made to our knowledge of this acid and its various combinations.

The diſtinguiſhing property of fluoric acid is that when dry and in the ſtate of gas it readily combines with ſilex, and ſtill retains its elaſtic form: hence ariſes the peculiar and almoſt inſurmountable difficulty of obtaining this ſubſtance in a ſtate of purity.

Fluoric acid is procured from fluor ſpar: for this purpoſe a quantity of the mineral being reduced to a *fine* powder is to be mixed in a thick glaſs retort with an equal weight of concentrated ſulphuric acid: upon the application of a gentle heat the ſulphuric acid will combine with the calcareous baſe of the ſpar, and fluoric acid gas will at the ſame time be liberated and may be received in the mercurial pneumatic apparatus in the uſual way. If the heat applied to the retort is ſomewhat conſiderable, and the gas is rapidly produced, the retort will give way in the ſpace of a minute or two being eaten into holes by the action of the acid; if the proceſs is conducted cautiouſly and at as low a temperature as poſſible the retort may be made to laſt a conſiderable while longer. The gas thus procured, while confined over mercury, is perfectly colourleſs and tranſparent; it has a pungent ſuffocating odour like muriatic acid, produces immediate death to animals which are immerſed in it, extinguiſhes the flame of a candle after having previouſly tinged its flame of a green colour, and changes certain vegetable blues to red. Its ſpecific gravity is conſiderably greater than that of atmoſpheric air, but has not yet been aſcertained with any accuracy. If this gas is mixed with atmoſpheric air a white vapour ſimilar to but more copious than that occaſioned by the muriatic acid gas in the ſame circumſtances is the reſult; this appearance is partly occaſioned by the combination of the acid with the moiſture of the air, but principally by the depoſition of ſilex, which takes place at the ſame time. The earth is in like manner depoſited if the gas is received in water, and this experiment according to the circumſtances under which the acid is diſengaged, exhibits a variety of ſingular and intereſting appearances. As ſoon as a bubble of gas paſſes from the beak of the retort into the water it is immediately diminiſhed in ſize from the abſorption of a portion of the acid, and the whole would be taken up if the globule did not inſtantly become coated with the earth depoſited by that part of the acid which is abſorbed, for the earthy film being interpoſed between the gas and the water prevents any further combination till the bubble reaches the ſurface of the water, where it burſts. If this is performed in a jar full of water inverted over mercury, and care is taken to prevent the gas from being mixed with atmoſpheric air, the whole of the gas is abſorbed, and the ſilex in proportion as it is depoſited diffuſes itſelf through the liquor, which thus at length acquires a gelatinous conſiſtence: when in this ſtate the greater part of the earth may be ſeparated by putting the whole in a piece of linen and ſqueezing it. The acid liquor thus procured being again inverted over mercury, will abſorb an additional quantity of gas, and by thus treating it three or four times ſucceſſively, a ſtrong fuming acid liquor may be obtained, conſiſting principally of fluoric acid and water, but ſtill holding in ſolution a portion of ſilex and probably alſo of alkali, from the decompoſition of the glaſs of the retort. If this ſaturated liquor is mixed with a few drops of fluat of ſilver a ſlight precipitate of luna cornea takes place,[a] and the fluoric acid is thus ſepa-

[a] Prieſtley's Experiments methodized II. p. 153.

rated from a ſmall portion of muriatic acid, which, when prepared in the foregoing manner, it is always found to contain. From the liquor thus purified a conſiderable quantity of pure fluoric acid gas may be obtained by heating it almoſt to ebullition, in a retort, and receiving the product in mercury. This gas appears to conſiſt merely of fluoric acid ſaturated with as much water as it can hold in an elaſtic ſtate, and at a moderately cool temperature ſeems to have no action on glaſs. It combines readily with water without depoſiting any earth, and has an aſtringent acidulous taſte. A candle immerſed in it is extinguiſhed without any previous change in the colour of the flame: it combines with ammoniacal gas forming a white cloud:[b] it diſſolves camphor, and is taken up in large quantity by oil of turpentine, to which it communicates an orange colour and a pungent acid odour. If kept for ſome time in a bottle of ſoft glaſs it acts upon it though ſlightly, on which account it is a uſeful precaution before putting the acid in, to line the bottle with a thin coating of a mixture of oil and wax.

It has been propoſed by ſome chemiſts, as a method of obtaining pure liquid fluoric acid, to make uſe of a leaden retort and receiver; in which caſe the fluor ſpar being previouſly reduced to an exceedingly fine powder is to be mixed in the retort with an equal weight of ſtrong ſulphuric acid; the application of a gentle heat, not exceeding that of boiling water, will force into the receiver a large quantity of acid gas, where it combines to ſaturation with water, and thus produces liquid fluoric acid. In this proceſs, provided the ſpar ſelected was free from quartz, there is indeed no depoſition of ſilex, but a very notable proportion of lead is volatilized, and remains for the moſt part diſſolved in the liquor, which, on this account, is by no means ſo pure as the acid produced by Dr. Prieſtley's method.

Fluoric acid has not yet been decompoſed, its baſe therefore is wholly unknown, and it is only from analogy that chemiſts ſuppoſe it to contain oxygen. A remarkable difference between the fluoric and muriatic acids is that the latter is incapable of becoming oxygenated: it will neither unite with oxygen in the ſtate of gas nor when digeſted with manganeſe. Fluoric acid combines with the alkalies and alkaline earths, with alumine and ſilex, and with the metallic oxyds; the metals in a reguline ſtate appear to have no affinity for dry fluoric acid, but when liquid it will diſſolve iron, zinc, copper, and arſenic, hydrogen being at the ſame time diſengaged. The order of its affinities is as follows, lime, barytes, ſtrontian, magneſia, potaſh, ſoda, ammonia, alumine, and ſilex.

The only uſe to which fluoric acid has been applied is engraving on glaſs. It appears from Beckman that this was firſt practiſed by an artiſt of Nuremburg, in the year 1670, who prepared his etching liquor by digeſting together nitrous acid and finely powdered fluor ſpar, for ſeveral hours on a warm ſand-bath, and then uſing the clear liquor as aquafortis is employed by the copper-plate engravers. But the knowledge and application of this liquor was confined to a few German artiſts, till, after the diſcoveries of Scheele and Prieſtley, the fluoric acid in a purer ſtate was uſed for the ſame purpoſe by various ingenious artiſts in England and France. Puymaurin found the liquid acid prepared in leaden veſſels according to Scheele's proceſs to anſwer very well for this purpoſe in warm weather, but by cold, its activity is ſo much impaired as to produce little effect even in three or four days. The gaſſeous acid however is much more efficacious, and being at the ſame time ſufficiently manageable with proper care, merits the preference. To engrave on glaſs, ſelect a piece of plate-glaſs of the requiſite ſize, cover it with hard engraver's wax, and with a needle or other ſuitable inſtrument trace the intended deſign as in common etching, obſerving that every ſtroke paſſes quite through the wax to the ſurface of the glaſs; which may be aſcertained by placing the plate on a ſloping frame like a portable reading deſk, in which ſituation the light will ſhine through wherever the wax is removed. When the etching is compleated, lay the plate with the engraved ſide downwards on a frame, in a box lined with ſtrong ſheet lead or thick tin foil, and place on the bottom of the box a few leaden cups containing a mixture of one part of very finely pulverized fluor ſpar and two parts of ſulphuric acid: then cloſe the lid of the box, and place it on a ſtove, or in any other convenient ſituation where it may be expoſed to as high a heat as it can bear without riſking the melting of the wax: fluoric acid gas will be copiouſly diſengaged, and in a ſhort time (from one hour to three, according to circumſtances), the plate will be found ſufficiently corroded.

FLUATS.

The compound ſalts formed by the union of

[b] Scheele's Eſſ. p. 28.

fluoric acid with the various ſalifiable baſes are denominated fluats, in the new nomenclature. Our knowledge of this genus of ſalts is as yet very imperfect, both becauſe few experiments have been made on the ſubject, and becauſe the acid employed has never been pure, but always more or leſs combined with ſilex, by which its effect in many caſes is very materially modified. The fluats are all decompoſable in the moiſt way by ſulphuric acid, and at a red heat by phoſphoric and probably boracic acid.

Fluat of Potash.

Cauſtic potaſh even when melted with fluor-ſpar in the proportion of four parts of the former to one of the latter is incapable of attracting from the lime any portion of fluoric acid; but if a ſolution of carbonated potaſh is ſubſtituted for the pure alkali a decompoſition is effected without much difficulty, fluat of potaſh, with exceſs of baſe being held in ſolution, and a precipitate of carbonated lime remaining at the bottom of the veſſel. The liquor being evaporated yields a ſaline maſs which remains unchanged in the air.[c] Fluat of potaſh may alſo be prepared by adding pure potaſh to the liquid acid, and the reſult is a gelatinous uncryſtallizable maſs, almoſt taſteleſs, and deliqueſcent in the air: this particular combination has not been analyzed, but in all probability contains ſilex. A fluat of potaſh, ſtill more charged with earth, is obtained by adding to the gelatinous acid liquor produced by the preparation of fluoric acid in glaſs veſſels ſome pure or carbonated potaſh: a precipitate is immediately thrown down, which when dry, ſeparates into minute white grains. This ſubſtance has an acid taſte, and is ſoluble in 150 parts of boiling water, from which it is again in part depoſited as the liquor cools. When melted, the ſilex and alkali run into a glaſs, and the acid is volatilized; it is not probable however that the whole of the acid is thus driven off except the experiment is performed in an earthen crucible. Lime water or muriat of lime being added to the ſolution of ſilicated fluat of potaſh, ſeparates nearly the whole of the alkali and cauſes a precipitate of ſilicated fluat of lime: a ſimilar effect is produced by ſulphat of magneſia.

Fluat of Soda.

This ſalt may be prepared in the ſame manner as the preceding by ſubſtituting ſoda and carbonat of ſoda in the place of potaſh and its carbonat. Fluat of ſoda cryſtallizes in ſmall rectangular figures: it has a bitter and ſomewhat ſtyptic flavour; it is permanent in the air, is little ſoluble in water, and may be obtained in cryſtals by ſpontaneous evaporation. It decrepitates when ſuddenly heated and then melts without loſing its acid into a ſemi-tranſparent vitreous maſs. Fluoric acid will take up both ſoda and ſilex at the ſame time, and the reſult is a ſalt which as far as it has been examined is analogous to ſilicated fluat of potaſh.

Fluat of Ammonia.

This ſalt may be obtained in a ſolid ſtate by adding one part of finely-pulverized fluor-ſpar to two parts of ſulphat of ammonia, and heating the mixture in a ſubliming apparatus; a little ammoniacal gas is firſt liberated and then the fluat of ammonia riſes and by degrees forms a cruſt on the inſide of the capital, ſulphat of lime being left behind. The ſame ſalt may be procured by ſaturating common fluoric acid with cauſtic or carbonated ammonia: a gelatinous precipitate of ſilex is firſt depoſited, and the clear liquor by ſlow evaporation ſhoots into minute tranſparent cryſtals. Theſe cryſtals when expoſed to heat in cloſe veſſels are in part decompoſed; ammonia is firſt given out and then there riſes an acidulous fluat of ammonia. Liquid fluat of ammonia is decompoſed at a very gentle heat by chalk, producing carbonat of ammonia and fluat of lime. Lime-water alſo produces a regenerated fluat of lime, and the ſame effect takes place with muriat and nitrat of lime. Sulphat of magneſia is alſo decompoſed by this ſalt; fluat of magneſia being precipitated.

Fluat of Lime.

We have already amply treated of the native fluat of lime, or fluor ſpar, in the preceding article; it remains therefore only to mention the little that is known of this ſalt artificially prepared. The affinity of lime for fluoric acid is ſtronger than that of any other baſe for the ſame acid; hence it may be prepared by adding lime-water or a ſolution of any calcareous ſalt to any other of the fluats, except perhaps fluat of magneſia; but the pureſt regenerated fluor is prepared by adding together fluat of ammonia to nitrat of lime; the fluat of lime falls to the bottom, and when properly edulcorated is in all probability entirely pure. This ſalt appears to be inſoluble in water, but is readily taken up by liquid fluoric acid. It is phoſphoreſcent when laid on a hot iron as native fluor is, and in like manner loſes this quality by being ignited. It is inſipid, unalterable by expoſure to the air, and at 51° Wedgw. melts into a colourleſs tranſparent glaſs. It is decompoſable

[c] Scheele's Eſſ. p. 13.

by ſulphuric acid and in part by the muriatic and nitric, and by the carbonats of potaſh and ſoda and moſt of the phoſphats.

FLUAT OF BARYTES.

All that is known of this ſalt may be related in a very few words. It is prepared by adding fluoric acid, or ſtill better an alkaline fluat, to nitrat or muriat of barytes; fluat of barytes is precipitated in a pulverulent form. This earthy ſalt is ſparingly ſoluble in water, and is decompoſed by lime-water, and by ſulphuric acid, the former attracting its acid and the latter its baſe.

FLUAT OF MAGNESIA.

Carbonat of magneſia being added to fluoric acid, the carbonic acid is given out with effervescence and the magneſia diſſolves. When the liquor approaches nearly to ſaturation the greater part of the fluat of magneſia, mixed alſo in all probability with ſilex, falls down in a ſemi-gelatinous ſtate. The ſupernatant liquor by gentle evaporation depoſits ſmall tranſparent hexagonal priſms terminated by trihedral pyramids. Theſe cryſtals are ſcarcely at all ſoluble in water, but are ſomewhat more ſo in alcohol: they are not decompoſed by heat, nor, according to Bergman, by any acid.

FLUAT OF ALUMINE.

Earth of alum is ſoluble in fluoric acid, and the compound by evaporation aſſumes a gelatinous conſiſtence, but does not cryſtallize. It is ſweet and aſtringent to the taſte, and always contains an exceſs of acid. It is not however a ſimple fluat of alumine but contains beſides, potaſh, and perhaps ſome ſilex. Fluoric acid may in like manner be made to unite with alumine and ſoda, and this combination is capable of aſſuming a cryſtalline form. It has even been found native, and has already been deſcribed under its mineralogical appellation CRYOLITE.

FLUAT OF SILEX.

When fluoric acid is prepared by the uſual proceſs in glaſs veſſels, it diſſolves a portion both of the earth and alkali of which they are formed, and produces a gelatinous fluid which may be conſidered as an acidulous fluat of ſilex and alkali. If this liquor is kept for a conſiderable time in a glaſs veſſel not entirely cloſed, it depoſits ſmall tranſparent ſhining cryſtals: theſe are partly ſoluble in the fixed alkalies, and give out fluoric acid by mere heat, or by any of the ſtrong mineral acids. Not only glaſs but felſpar, and probably all minerals that contain ſilex and potaſh, are very eaſily acted on by fluoric acid in a gaſſeous ſtate, but the ſofteſt of the ſiliceous ſtones that contain no alkali, ſuch as opal, are attacked by it with much greater difficulty. The properties of pure fluat of ſilex have not yet been examined.

FLUOR VOLATILE ALKALI, a term for cauſtic liquid ammonia, now diſuſed.

FLUX. *Fluſs*, Germ.

A flux in chemiſtry means any ſubſtance which is added to another in order to aſſiſt its fuſion when heat is applied. Thus alkali is a flux for flint, as, when mixed with it in due proportion and heated, it cauſes it to melt into the compound called glaſs.

The term flux is almoſt excluſively applied in chemiſtry to thoſe ſubſtances, often ſaline mixtures, that are added to minerals or metallic ores to aſſiſt in the proceſs of reduction. The general uſe of reducing fluxes, their advantages and inconveniences, are detailed in the deſcription of the aſſay of the ores of COPPER, to which we ſhall refer the reader, and alſo to the methods of aſſay in the dry way of the ores of the other metals, particularly of IRON.

The White Flux is made ſimply by mixing equal parts of tartar or cream of tartar and nitre and deflagrating them in a clean crucible. The nitrous acid burns the carbonaceous part of the tartar, and the mixed alkalies of the nitre and tartar alone remain. This flux is therefore little elſe than a pure ſubcarbonat of potaſh.

The Crude Flux is the former mixture before deflagration.

The Black Flux is the moſt commonly employed of all the ſaline reducing fluxes. It is made by deflagrating in a large crucible a mixture of one part of nitre with two of tartar, and differs from the former in containing beſides carbonat of potaſh a quantity of charcoal of the tartar, which there has not been nitre enough to conſume. It therefore both aſſiſts in the fuſion of ores by its alkaline ingredient and diſoxygenates and reduces them to the metallic ſtate by means of its carbon.

In making this flux, the materials, previouſly well mixed, ſhould be thrown by ſmall quantities into a red-hot crucible, and looſely covered after each projection, and as ſoon as the laſt portion is deflagrated it ſhould be removed from the fire and kept in well-cloſed bottles to prevent the deliqueſcence of the alkali.

FORMIC ACID or ACID OF ANTS. *Ameiſenſaure*, Germ.

The exiſtence of an acid in theſe inſects was proved by unequivocal ſigns long before its exact nature was underſtood. If an ant-hill, eſpecially of the ſmall red ſpecies be turned up or in any way diſturbed ſo as to irritate the

inſects, a very pungent acid vapour is perceived, which excites coughing, brings tears in the eyes, and in great intenſity almoſt ſuffocates. If a piece of paper ſtained with litmus is held in this vapour it very ſpeedily reddens as in any other acid vapour. Ants ſeem alſo conſtantly to exhale an acid whether irritated or not, ſo that the ſame changes produced on flowers and leaves by the known acids, take place when they are laid in the track of theſe inſects, and it is conjectured that a part of the irritation cauſed by their bite is owing to the inſertion of a portion of their native acid.

Margraaf [a] was the firſt who procured the acid in ſubſtance by diſtillation of theſe inſects, and the valuable reſearches of Arvidſon, [b] Bucholz, Deyeux, [c] and Fourcroy and Vauquelin have thrown further light on the nature of this ſingular animal product.

Margraaf extracted the acid in the following way: a quantity of theſe inſects collected in May and June was put into a large retort, water being poured upon them, the whole was diſtilled with a fire ſlowly encreaſed to boiling. This proceſs, continued till the product came over coloured, afforded an acid liquor on which a quantity of oil was floating, which became of a ſuetty conſiſtence when cold. To ſeparate all the acid, the reſidue in the retort was preſſed and the acid liquor mixed with the acidulous water in the receiver, ſeparated from the oil, and rediſtilled with care. The firſt portion, which was ſcarcely acid, was rejected, after which the diſtilled liquor was collected as long as it was free from empyreuma. This is the formic acid in conſiderable purity, but the dark and fouled reſidue in the retort ſtill contains much of the acid, which may be ſeparated by diſtillation in a water bath, if thought proper.

A more concentrated acid may be prepared in the way uſed by Arvidſon. Collect a number of ants by laying a clean ſtick on an ant-hill repeatedly, and ſcraping them off into an alembic full of cold water. When this is quite full pour off the water (the uſe of which is to kill and waſh the inſects) and diſtil with a gentle heat till the liquor begins to flow foul and oily. Or the ants previouſly killed by water may be tied in a linen bag immerſed in boiling water and repeatedly preſſed till all the acid is extracted, which may then be purified by diſtillation. In any of theſe methods ants will yield nearly half their weight of an acid, which has a very ſharp ſour acrid taſte, and when purified by ſimple diſtillation is of about 1.0075 ſpecific gravity. By repeated rectification it may be brought to about 1.0453.

A full enumeration of its properties and combinations is needleſs in this place, as it is found to be compoſed of the acetic acid, but mixed with a ſmall portion of another acid, which appears to be the malic, holding in ſolution a certain and inſeparable quantity of acrid volatile oily matter, or ſomething of the kind, which gives the peculiar taſte and ſmell that diſtinguiſh this acid from a ſimple mixture of the acids of which it appears to be compoſed.

A ſingular way of preparing the formiated alkalies in ſmall quantity, is to lay cloths wetted in the alkali over the ant-hills and paths of theſe inſects. After a time the alkali becomes ſaturated with the acid excretions of the animal, and the neutral ſalt thus formed may be extracted by lixiviation.

The analytical experiments of Fourcroy and Vauquelin [d] on this acid may be added, as they prove its compound nature, and are important.

A quantity of ants was collected, cleaned and killed with cold water and bruiſed in a marble mortar, during which they exhaled a very ſharp pungent odour like that of radical vinegar. They were then macerated for ſeveral days in alcohol, which became of a yellow colour. This alcoholic infuſion was then diſtilled and gave an acid inflammable liquor. The reſidue in the retort was a very acid liquor mixed with a red extract, from which it was ſeparated by the filter. The acid was then ſaturated with lime, and gave a brown thick nauſeous liquor.

This formiat of lime had the following properties: mixed with ſulphuric acid it exhaled a ſtrong odour of vinegar: with nitrat of lead, gave a copious white precipitate; and with nitrat of ſilver, a yellowiſh precipitate. The mixture of formiat of lime and ſulphuric acid being diluted and diſtilled yielded a clear, very acid, empyreumatic liquor, which now gave no precipitate with the ſalts of lead, and when combined with potaſh gave cryſtallized acetite of potaſh; with ſulphuric acid gave radical vinegar; and with nitrat of mercury gave a flaky precipitate of acetite of mercury. The acid liquor therefore obtained from the formiat of lime by diſtillation with ſulphuric acid, was fully aſcertained to be the acetic acid mixed with ſome animal matter that gave the acid empyreuma.

But the formiat of lime alſo gave a copious

[a] Mem. Acad. Berlin, 1749. [b] Bergman's Opuſcula. [c] Journ. Phyſ.
[d] Aanales du Muſeum Natl. or Phil. Mag. vol. 15.

precipitate with nitrat of lead, which pure acetite of lime will not do, and as this decomposition of the ſalts of lead was not found to be affected by the *diſtilled* acid above mentioned, it follows that this other acid is one that is fixed in a moderate heat, or elſe is ſo altered by the action of heat and ſulphuric acid as no longer to retain its proper character. As it could not be examined with any convenience in the reſidue of the ſulphuric acid and formiat of lime, on account of the embarraſſment which the preſence of ſulphuric acid itſelf would produce, a large portion of the formiat of lime was mixed with nitrat of lead, and the white precipitate thus produced was ſeparately collected and examined. It therefore conſiſted of oxyd of lead combined with the unknown acid, which, by further examination, was found to exhibit all the characters of the MALIC.

The quantity of acid contained in theſe inſects is very ſuprizing, and far exceeds what is found in any other known part of the animal creation. It is obviouſly not a *product* of any chemical proceſs uſed for the extraction, ſince the living inſect abounds with acid, and produces the known effect of an acid on every thing that it touches.

FORMIATS are ſalts produced by the combination of the formic acid with alkaline, earthy, or metallic baſes. From what has preceded, it will appear that the formiats are very intimate compounds of the acetite and malat of the baſe employed, together with a portion of acrid animal matter, the nature of which is little known.

FRAUENEIS. See GYPSUM.

FREEZING.

The theory and principal circumſtances attending congelation having been detailed under the article CALORIC, we ſhall in this place merely relate ſome of the principal means employed for producing *artificial cold*, for experimental and economical purpoſes.

The preſervation of ſnow or ice during the ſummer months is almoſt a neceſſary of life in hot countries, and an object of uſeful luxury in temperate climates. The conſtruction of ice-houſes is in general very ſimple, often indeed they conſiſt of nothing more than deep caves hollowed out in the coldeſt ſide of mountains, and filled with ice or ſnow rammed down with much manual labour. Ice may generally be preſerved during the ſummer, if the place ſelected be cool and thoroughly ſheltered from the direct influence of the ſun, if the ice be kept in conſiderable maſs, with as few interſtices as poſſible, lined with ſtraw, reeds, or any looſe ſubſtance of the kind, which is a bad conductor of heat, and eſpecially if it be kept dry both by avoiding external moiſture and by giving an exit to the water formed by the ſlow liquefaction of the outer part of the maſs. The common ice-houſes are uſually placed in the ſhadieſt and cooleſt part of a wood, and conſiſt of caves about eight or ten feet in depth, lined with maſonry, unleſs cut out of a dry rock, finiſhed at the bottom in the form of a ſugar loaf, and the whole lined with a conſiderable thickneſs of thatch, ſtraw, or reeds. The ice when thrown in is broken down as much as poſſible, that it may lie cloſe, and when filling, water may be thrown on it, which by freezing will cement the whole into a hard ſolid maſs penetrable only by the pickaxe. When filled it is covered very carefully with earth and thatch, leaving only a ſmall entrance with a door at each end alſo very cloſely lined.

The ſnow-caves in Italy are no more than deep pits dug in the north ſide of a hill, lined with ſtraw, and furniſhed with a ſmall tap-hole at bottom to carry off the water formed by melting. The ſnow is rammed very hard, and if well laid up will keep during the whole ſummer.

But in tropical climates far diſtant from high mountains, as neither natural ſnow nor ice can be obtained, recourſe is had to the cold generated by evaporation and the comparative coolneſs of the air a little before day-break, to manufacture ice in large quantities, and thus to ſupply a moſt grateful luxury at a moderate price. Ice is thus ſimply manufactured in the large way at Benares, Allahabad, and Calcutta, where natural ice has never been ſeen.[a] On a large open plain an excavation is made about thirty feet ſquare and two deep, on the bottom of which ſugar-cane or maize ſtems are evenly ſtrewed to the height of about eight inches. On this bed are ſet rows of ſmall ſhallow unglazed earthen pans, ſo porous that when filled with water the outſides are immediately covered with a thick dew oozing through them. Towards the duſk of the evening, the pans previouſly ſmeared with butter, are filled with ſoft water generally boiled, and let to remain there during the night. In the morning before ſun-riſe the ice-makers attend and collect from each pan a cruſt of ice more or leſs thick that adheres to the inner ſide, and is put into baſkets and carried without loſs of time to the common receptacle, which is a deep pit in a high dry ſituation, lined firſt with

[a] Barker Phil. Trans. vol. lxv. and Williams's ditto vol. lxxxiii.

ſtraw and then with old blanketing, where it is beaten down and congeals into a ſolid maſs. The crop of ice varies extremely, ſometimes amounting to more than half the contents of the pan, at other times ſcarcely a pellicle. Clear and ſerene weather is the moſt favourable for its production whatever be the ſenſible heat of the atmoſphere. The cold generated by the rapid evaporation round every part of the pan is the cauſe of this congelation. When uſed for the table, the ice is either added to the liquor to be cooled, or is put into a large veſſel mixed with ſalt or nitre, and the ſherbet, creams, and the like, intended to be frozen, are incloſed in thin ſilver veſſels and immerſed in the mixture. In this way ices are procured for the table, when the heat even in the ſhade is very commonly above 100°.

At the ice manufactory at Benares about 100,000 pans are reckoned to be expoſed at a time, and the buſineſs of filling them at night and gathering the ice in the morning employs about 300 men, women, and children.

It is neceſſary that the cane-ſtalks be kept perfectly dry, if by accident any part becomes wetted, no ice will form in the pans above.

Mr. Williams found the temperature of the air on the cane-ſtalks never to be lower than 36°, and even plenty of ice would form in the pans when it was as high as 40°. What is remarkable, he found that ice was beſt formed with the gentleſt winds, at which time a thermometer placed on the ſtraw would always ſtand about 4 degrees lower than one fixed to a pole five feet higher, but in ſtrong winds no ſuch difference was obſervable, and then no ice was formed.

To compare the effect of the poroſity of theſe veſſels in lowering the temperature of water contained in them, Mr. W. took a new pot and one in which by long uſe the pores had been nearly ſtopped, and placed them in a hot weſterly wind in the ſhade, where the heat of the air was 100°. On expoſure for four hours the water in the old pot was 97, and that in the new pot was only 68°.

Many other inſtances of artificial cold produced by evaporation might be brought, many of which are detailed under the article CALORIC.

Another mode of producing cold is by freezing mixtures, or ſaline ſubſtances of various kinds, which during their liquefaction either by ſolution in water or in acids, abſorb a vaſt quantity of caloric from all ſubſtances in contact with them. As a general rule it may be obſerved that, all the compound ſalts produce a certain degree of cold during ſolution, and this effect is, *ceteris paribus*, the greater when the ſalts are naturally deliqueſcent and contain a large quantity of water of cryſtallization. The cryſtallized alkalies (that is the pure alkalies) alſo generate a moſt intenſe cold, as alſo do the acids when mixed with water already frozen.

It is ſomewhat doubtful whether or not the cold produced thus artificially equals the greateſt degree of natural cold ever obſerved in any part of the world. Theſe reſearches have been a good deal connected with the attempts to freeze mercury, partly on account of this fluid being the commoneſt thermometrical meaſure of heat, and partly becauſe its real congelation was long a matter of doubt and incredulity, and though now a fact fully proved and not difficult to be effected, it requires an extreme intenſity of cold for the purpoſe. The freezing point of mercury is found to be about —39 or —40 Fahr. and between this point and moderate ſummer heat are included all the primary diminutions of temperature produced by all the known freezing mixtures, or thoſe that occur on the mixture of the freezing materials *not previouſly cooled*. But by two or three combined and ſucceſſive operations, that is, by employing one freezing mixture to cool the materials for the next, and the latter perhaps for a third, a degree of concentrated cold has been generated which exceeds that of freezing mercury by at leaſt 30 or 40 degrees, if the contraction in the alcohol thermometer (the only one of uſe in theſe caſes) continues ſufficiently uniform in its loweſt degrees, which there is little reaſon to queſtion. But as in ſome parts of Siberia and of the North of America, mercury has been known to freeze with great eaſe when ſimply expoſed to the air for a ſhort time, it is ſtill uncertain whether artificial cold produced by chemiſts in ordinary atmoſpheric temperatures has ever equalled the natural cold of theſe climates, in which however man has exiſted.

Among the vaſt variety of freezing mixtures we may ſelect ſome of the moſt important and the earlieſt of application, and particularly refer the reader to the numerous and intereſting experiments of Mr. Walker on artificial cold,[b] who ſeemed nearly to have exhauſted the ſubject till the diſcovery by Lowitz of the aſtoniſhing frigorific effects of cryſtallized cauſtic potaſh, and the nearly equal powers of muriat of lime, which will be preſently noticed.

[b] Phil. Tranſ. Vol. lxxvii, lxxviii. lxxix. lxxxiii. lxxxv. & xci.

The freezing mixtures may be with convenience claſſed (with Mr. Walker) into thoſe in which ſaline ſubſtances are mixed with each other or with water, that is at a common temperature, and thoſe that require the uſe of water already congealed in the form of ſnow or powdered ice. Theſe in a tabular form are the following:

Cryſtallized Salts in Powder.	*Liquor.*	*Reduction of therm. from 50° to*
Muriated ammonia 5: and nitre 5	with water 16	— 10
Muriated ammonia 5: nitre 5: ſulphated ſoda 8	ditto 16	— 4
Nitrated ammonia 1.	ditto 1	— 4
Nitrated ammonia 1: carbonated ſoda 1.	ditto 1	— 7
Sulphated ſoda 3.	dil: nitre a. 2	— 3
Sulphated ſoda 6: muriated ammonia 4: nitre 2.	ditto 4	— 10
Sulphated ſoda 6: nitrated ammonia 5.	ditto 4	— 14
Phoſphated ſoda 9.	ditto 4	— 12
Phoſphated ſoda 9: nitrated ammonia 6.	ditto 4	— 21
Sulphated ſoda 8:	muriat. a. 5	0
Sulphated ſoda 5:	dil. ſulph. a. 4	— 3

In the above mixtures the ſalts to produce their fulleſt effect ſhould be recently cryſtallized, in fine powder, and containing as much water of cryſtallation as poſſible, but not damp. The mixture ſhould be made in a thin metallic (or where the acids are uſed) a thin glaſs veſſel, the ſalts, when of more than one kind, being ſucceſſively added to the liquor in the order in which they ſtand and immediately ſtirred together. The cold continues during the ſolution of the ſalts and generally reaches its greateſt intenſity almoſt immediately on mixture, but with ſome ounces of the materials it continues very intenſe for a conſiderable time, and the effect may be advantageouſly prolonged by adding after a while a little more of the powdered ſalts. The figures in the table expreſs the parts by *weight*, but where water is the liquor it may be *meaſured*, the common ounce meaſure being ſufficiently accurate. The degree of dilution of the nitric acid is two parts by weight of the moſt concentrated acid diluted with one part of water, and the dilute ſulphuric acid implies equal weights of the ſtrong acid and water. Theſe acids ſhould be previouſly mixed with water that the heat on mixture may have eſcaped. All the above materials are taken at the common temperature of 50°. as this is as high as well-water ever riſes to in the middle of ſummer, and therefore may generally be obtained by cooling the materials therein. But if a higher temperature be begun with, a greater proportion of the ſalt ſhould be uſed. The cold produced by all theſe mixtures is found by inſpecting the table to be very intenſe, but it muſt be remembered that it expreſſes the utmoſt effect, where the ſubſtance immerſed is only the ſmall bulb of a fine thermometer, and therefore where the caloric transferred from the bulb itſelf to the freezing mixture is too ſmall materially to counteract the cooling power.

But when theſe mixtures are uſed as the means of reducing the temperature of water or other ſubſtances immerſed in them, the effect will of courſe fall greatly ſhort of the degree here indicated, the refrigeration being in inverſe proportion both to the bulk and the capacity for caloric of the ſubſtance immerſed. The firſt of theſe mixtures, that is muriated ammonia, nitre, and water, will ſerve again any number of times, the ſalts being recoverable undecompoſed by the ſimple evaporation of the water.

The above being the frigorific power of the ſeveral mixtures at an ordinary temperature, it is obvious that their effect will be augmented though in a decreaſing ratio by cooling the materials of one mixture by previous immerſion in another. In this way Mr. Walker was able to congeal mercury without uſing a particle of ice or ſnow by mixing nitro-ſulphuric acid cooled to — 30 with ſulphat of ſoda alſo cooled to — 14. This produced a cold of — 54 and was ſufficient to freeze a ſmall quantity of mercury immerſed in it.

Another claſs of freezing mixtures and by far the moſt powerful, are thoſe in which one of the materials is ſnow or powdered ice, and the other either an acid or an alkali or a neutral ſalt, or a mixture of ſome of theſe. The two that have been the longeſt known and are familiar to all chemiſts are common ſalt and ſnow, and nitrous acid and ſnow. Fahrenheit firſt aſcertained that when equal parts of ſalt and ſnow are mixed together, a cold of 32 degrees below the water-freezing point of his thermometer is produced, which he was led to aſſume

as the zero of his thermometer. According to Mr. Walker a double proportion of ſnow produces a cold 5 degrees lower, and other ſalts with ſnow have ſtill greater powers as appears by the following table:

Muriat of ſoda 1. - - - - -	with ſnow 2	produces a cold of	— 5
Muriat of ſoda 2: muriat of ammonia 1. -	ditto 5	- - - - - - -	— 12
Muriat of ſoda 10: Muriat of ammonia 5: nitre 5:	ditto 24	- - - - - - -	— 18
Muriat of ſoda 5: Nitrated ammonia 5. - -	ditto 12	- - - - - - -	— 25

and muriat of lime has a ſtill greater effect as will preſently be mentioned.

The above mixtures are taken at any common temperature.

In all theſe mixtures with ſnow the latter muſt be newly fallen, dry, light and uncompreſſed.

Nitrous acid and ſnow is another moſt powerful freezing mixture, the powers of which have long been known, and were reſorted to in the firſt attempts to freeze mercury by artificial cold. The acid ſhould be either the fuming acid *undiluted* or the pale concentrated acid diluted with one fifth of its weight of water. The neceſſity of this laſt was diſcovered by Mr. Cavendiſh, who found that this acid cooled to 32°, gave out a quantity of heat, and had its temperature raiſed by the firſt addition of ſnow, and when again cooled to 32° the thermometer again roſe on adding more ſnow till about one fifth of the weight was added, after which no further interference with the frigorific effect took place.

Nitrous acid, either fuming and concentrated, or pale and properly diluted, when cooled to +32° added to freſh ſnow at the ſame temperature produces an inſtant cold of about —30°, and a very ſudden liquefaction of the ſnow as if it were laid on a hot iron. The beſt proportions ſeem to be about one part of the acid to two parts, or rather leſs, of the ſnow. This is therefore not quite ſufficient to freeze mercury in one operation, but if the acid and ſnow are previouſly cooled conſiderably, a ſmall portion of this metal encloſed in a thin glaſs bulb will readily congeal. Thus if the acid and ſnow are each cooled as low as 0. or even a few degrees higher (which a mixture of ſalt and ſnow will readily effect) and then mixed, a cold of about —46 which will freeze mercury, will be generated. The ſame effect will take place according to Walker by adding ſnow at +32° to nitrous acid cooled to —29°; or ſnow at +25° to nitrous acid at —20°; or ſnow at +20° to nitrous acid at —12°. In theſe caſes therefore the acid only need be cooled, the given temperatures of the ſnow occurring naturally every winter, and ſometimes, though rarely, a natural cold is felt in this country of a few degrees only above 0. at which time a mixture of nitrous acid and ſnow at that temperature will alone give a cold to freeze mercury. Ice rubbed to fine powder in a temperature below +32° (to prevent its getting damp by thawing) anſwers full as well as ſnow, and hence as ice may be procured at any time mercury may be hereby frozen by a ſucceſſion of cooling operations even in the midſt of ſummer.

Sulphuric acid, diluted with its own weight of water, and alſo ſtrong muriatic acid added (each being at +32°) to ſnow, produce a cold of very great intenſity, though ſome degrees leſs than the nitric acid.

Two other moſt powerful frigorific mixtures have been diſcovered by Profeſſor Lowitz, namely, cauſtic potaſh and ſnow, and muriat of lime and ſnow.

Potaſh in its common ſtate is prepared by rendering the carbonat cauſtic by means of lime, and evaporating the ſolution of alkali firſt to dryneſs and then encreaſing the heat to gentle fuſion of the alkali, and cooling it in cylindrical moulds. The alkali thus prepared is ſeldom free from ſome lime, and alſo is totally deprived of all water of cryſtallization, and if in this ſtate it is mixed with water a conſiderable quantity of heat is extricated, ſo as to make the mixture ſenſibly warm to the touch. But on the other hand if the alkali is diſſolved by alcohol and then cryſtallized (in the manner mentioned under the article *Potaſh*) in this ſtate Profeſſor Lowitz found that on mixture with water much cold was generated, and with ſnow, a greater cold was produced than has hitherto been effected by any known combination. Theſe experiments are curious.[c] Twelve ounces of cryſtallized potaſh added to as much water, each at 59° Fahr. ſunk the thermometer immediately to 33°. Four pounds of the alkali added to a pound of water at 33° gave a cold of 16°. With ſnow the effect was more ſtriking. At the temperature of 19°, ſix ounces of potaſh with as much ſnow immediately ſunk the thermometor to —42.5°

[c] Ann de Chem. tom. 22.

in which ſix ounces of mercury congealed in a few minutes. The ſame ſucceeded in a room whoſe heat was 59°. At a natural heat of 30° the ſame chemiſt made the following comparative experiments. Cryſtallized potaſh gave with ſnow a cold of — 45, fuſed potaſh deprived of water of cryſtallization, gave — 15°: a very concentrated ſolution of potaſh gave — 28: cauſtic ſoda, — 15: liquid ammonia, only + 20°: dilute nitric acid, — 10°: ſtrong fuming nitrous acid, — 23: ſtrong ſulphuric acid, — 10: muriatic acid, 29: ſtrong acetic acid, — 17.

Reflecting on the ſuperior frigorific powers of potaſh over the other ſalts, Profeſſor Lowitz was induced to aſcribe it chiefly to its great deliqueſcence, and hence made a trial of the other deliqueſcent ſalts, and particularly muriat of lime, and found it almoſt if not quite to equal the cryſtallized potaſh in this reſpect, and it has the great advantage of being very cheap, and of not injuring the ſkin of the hands by touching, which can hardly be avoided upon uſing the potaſh whatever precaution be taken.

Muriat of lime deſerves particular attention as being the cheapeſt and moſt uſeful frigorific material hitherto known, and of extreme energy. The ſalt is often to be had at a very cheap rate, being a reſidue (hitherto uſeleſs) of the diſtillation of ammonia. To prepare it, the ſaturated ſolution ſhould be evaporated to the conſiſtence of a ſyrup when hot, and as it cools nearly the whole will congeal into a ſemi-tranſparent yellowiſh maſs. This well dried ſhould be reduced to fine powder in a dry cold air, and kept in a bottle very carefully cloſed. If theſe precautions are not taken, the ſalt very readily deliqueſces, and is then unfit for frigorific purpoſes till again evaporated and cryſtallized. But as it is very readily prepared, it is better in moſt caſes not to attempt the drying and powdering till a little before it is to be uſed; for when long kept even in a moderate temperature, ſome dampneſs is almoſt unavoidable.

The experiments of Profeſſor Lowitz ſhew that conſiderable cold is produced by different proportions of this ſalt and *water*. The greateſt diminution of temperature obſerved was 34 degrees, which was produced on adding 15 parts of muriat of lime to 10 parts of water.

When this ſalt and ſnow or powdered ice are mixed together, the cold produced is very intenſe, as will be ſeen by the following obſervations of the ſame chemiſt.

At a natural temperature of 26° ſix ounces of ſnow were mixed ſucceſſively with the following proportions of the muriat dry and in fine powder,

	ounce.	
with	1	gave — 10° of cold
	2 - -	— 24.
	3 - -	— 36
	4 - -	— 44½
	8 - -	— 55

No greater cold was produced with any higher proportion of the muriat, and therefore the beſt proportions are three of the muriat to two of ſnow. The whole quantity ſhould be mixed together as ſpeedily as poſſible, and the ſnow ſhould be newly fallen, light, quite dry, and not conſolidated by freezing on the ground, which would render it hard and lumpy.

Theſe intereſting experiments have been repeated in different countries and with uniform ſucceſs,[d] and as the congealing point of mercury is about — 39, this metal may readily be frozen at the common temperature of our froſts, that is, from about 20° to 32°, without any previous preparation, ſimply by mixing together the muriat of lime and ſnow or dry powdered ice. Meſſrs. Fourcroy and Vauquelin, on mixing 8 ounces of muriat of lime with 6 ounces of ſnow at a natural temperature of 18°, reduced the alcohol thermometer in a few ſeconds to — 64°, and 8 ounces of mercury added to the mixture incloſed in a thin glaſs capſule, congealed in a very ſhort time cryſtallizing in octohedrons.

The particulars of an intereſting experiment made by Mr. Pepys [e] and other chemiſts in London, deſerve notice from the large quantity of mercury frozen, and the great intenſity to which the cold was carried, and the proportions of ingredients employed for the purpoſe.

The temperature of the laboratory being 33° a mixture of 2 pounds of muriat of lime at 33, and as much ſnow at 32° was made, and *fifty-ſix pounds* of mercury tied up in a ſtrong bladder was firſt immerſed in it. The mixture gave at firſt a cold of — 42. When it had riſen to + 5, by the contact of the mercury the latter was removed to another mixture in every reſpect ſimilar to the former till it was cooled to — 30. While this was going on 5 pounds of muriat of lime were put in a japanned iron pail, ſtanding in an earthen pan containing four pounds of muriat of lime and as much ſnow (and prevented from touching the bottom by means of corks) by which the muriat in the pail was cooled to — 15. As much ſnow at + 32° was then added to the pail, which reduced the temperature therein to the extreme cold of — 62, and the mercury, previouſly cooled in the way

[d] Ann. Chem. tom. 29. [e] Phil. Mag. vol. 3.

above mentioned to — 30, was immerſed in the pail, and the whole covered with a cloth and ſuffered to remain. In an hour and forty minutes the whole mercury was found to be ſolidified, and the freezing mixture then had riſen from — 62 to — 46, that is, 16 degrees higher than when the mercury was put into it. The mercury was then cut and divided in various ways, bent with pincers, and ſhewed all the marks of a malleable metal before it returned to the liquid ſtate.

It may be added, that if merely the congelation of mercury is wanted, the readieſt way is to throw a little of the metal looſe in a pretty large maſs of the freezing materials, where it will congeal in a few minutes; but where this experiment is performed in a room with a number of perſons ſtanding round, the natural temperature will be ſo much raiſed that the operator can hardly depend on ſucceſs, without previouſly cooling the muriat by a ſeparate mixture of the ſame materials. It is alſo of great importance that the ſnow ſhould remain without doors till the moment that it is wanted, and the whole of the muriat ſhould be kept cold by immerſing in ſnow or iced water the bottle that contains it. Great caution ſhould be uſed in touching frozen mercury. It gives an immediate ſenſation like a wound from a rough-edged inſtrument, or as if the finger was ſqueezed in a vice, and the mere ſenſation can hardly be diſtinguiſhed from the burn of red-hot iron. The part in contact immediately becomes quite white and numb, and there is no doubt that if it were to remain a very little time in contact with the frozen metal, a local gangrene like that of a common froſt-bitten limb, would come on. It is removed by rubbing the part a little time with ſnow.

We may cloſe this article with mentioning ſome miſcellaneous facts obſerved on the effect of a cold of — 40 or upwards on various bodies.

Red fuming nitric acid congeals into a thick maſs like butter, loſing all its ſuffocating odour.

The ſulphuric and acetic acids become quite ſolid.

The ſtrong muriatic acid has not hitherto been frozen by any cold.

Rectified oil of turpentine becomes thick and ropy at — 50°.

Sulphuric ether firſt becomes milky, then cryſtallizes with the loſs of all its odour.

Liquid ammonia congeals into a thick jelly like the liquor ſilicum.

None of the gaſſes have yet been reduced to a ſolid ſtate by any intenſity of cold.

FRENCH CHALK. See STEATITE.

FRENCH BERRY. See AVIGNON BERRY.

FRITT is a porous ſpongy maſs ariſing from partial calcination of the materials of glaſs in the proceſs of this manufacture. See GLASS.

FUEL. The materials uſed as fuel in chemical proceſſes are chiefly coal, coke, and charcoal, each of which has its appropriate uſe, and concerning which ſome particulars will be mentioned under the article FURNACE. *(See the Appendix.)*

FULLERS EARTH.[a] *Walkererde*, Wern. *Terre a Foulon*, Broch.

The colour of this mineral is greeniſh-white, greeniſh-grey, olive and oil green; or light yellowiſh green, and yellowiſh grey paſſing into pale ochre yellow. Its colours are ſometimes diſpoſed in ſpots and ſtripes. It occurs only in maſs; and is without luſtre. Its fracture is uneven paſſing into large conchoidal and flaty, or fine grained earthy. It breaks into indeterminate blunt edged or flaty fragments. It is opake, ſufficiently ſoft to be ſcratched by the nail, and brittle. It takes a poliſh by friction, adheres very ſlightly to the tongue, and is unctuous to the touch. It is moderately heavy, but its ſpecific gravity has not been accurately aſcertained.

It does not become plaſtic with water, but when immerſed in this fluid, eſpecially when warm, it breaks down into a fine powder. It does not efferveſce with acids: before the blowpipe it melts into a brown ſpongy ſcoria. The conſtituent parts of the Fuller's earth of Hampſhire, according to an analyſis by Bergman, are

Silex - - -	51.8
Alumine - -	25.
Lime - - -	3.3
Magneſia - -	0.7
Oxyd of iron -	3.7
Water - - -	15.5
	100.0

There appear to be two diſtinct formations of Fullers' earth, or rather, two different minerals ſeem to be confounded under the ſame name. The Fullers' earth of Saxony belongs to the primitive rocks, being found under ſtrata of flaty grünſtein, and paſſing by degrees into this very mineral, hence it conſiſts of the ſame materials either originally depoſited in this looſe

[a] Emmerling, Brochant, Jameſon.

ſtate or having acquired this conſiſtence from decompoſition. The Engliſh Fullers' earth on the other hand is always found in beds covered by and reſting upon that peculiar and hitherto undeſcribed ſand-ſtone formation which accompanies and ſerves as the foundation to chalk: its colour is yellowiſh grey with a very faint ſcarcely perceptible tinge of green. It is found in Hampſhire, near Woburn in Bedfordſhire, and at Nutfield in Surry; at this latter place it is often mixed with cryſtallized heavy ſpar (ſulphated barytes) of a yellowiſh-grey paſſing into very high and clear wine colour.

Fullers' earth uſed formerly to be in high requeſt among the Engliſh manufacturers for clearing woollen cloth from the oil and greaſe which it acquires during the proceſs of manufacture, and its exportation was forbidden under the ſevereſt penalties: in conſequence however of the general ſubſtitution of ſoap for this purpoſe it is now almoſt wholly diſuſed.

FULMINATION. This term differs from detonation only in degree: they both imply a rapid decompoſition accompanied by a loud noiſe either with or without flame; but in thoſe ſubſtances which have obtained the name of fulminating, the exploſion is louder than in thoſe which are ſaid to detonate.

FULMINATING GOLD. See GOLD.

FULMINATING MERCURY of Bayen.

——————————— of Howard. See MERCURY.

FULMINATING POWDER.

This ſubſtance is thus prepared. Take three parts of nitre, two parts of purified pearlaſh (Kali preparatum, *Lond. Pharm.*) and one part of flowers of ſulphur, mix the whole very accurately in an earthen mortar and place it on a tile or plate before the fire till it is perfectly dry: then transfer it while hot into a ground ſtoppered bottle, and it may be kept without injury for any length of time. In order to experience its effects pour from ten to forty grains into an iron ladle and place it over a ſlow fire: in a ſhort time the powder becomes brown and acquires a paſty conſiſtence, a blue lambent flame then appears on the ſurface, and an inſtant after the whole explodes with a ſtunning noiſe and a ſlight momentary flaſh. If the maſs is removed from the fire as ſoon as it is fuſed, and kept in a dry well cloſed vial, it may at any time be exploded by a ſpark, in which caſe it burns like gunpowder, but more rapidly and with a greater detonation, but this effect cannot be produced on the unmelted powder how accurately ſoever the ingredients of it are mingled together. When fulminating powder is in fuſion, but not heated to the degree neceſſary to produce the blue flame, a particle of ignited charcoal thrown upon it will occaſion immediately a remarkably loud exploſion. [a]

It appears that the ingredients of the powder above mentioned do not acquire their fulminating property till combined together by fuſion; that is till the potaſh and ſulphur form ſulphuret of potaſh. Hence fulminating powder may alſo be made by mixing ſulphuret of potaſh with nitre, inſtead of adding the ſulphur and alkali ſeparate.

The cauſe of detonation, that is, of the loud noiſe by which it is characterized, is not very well underſtood: it uſed to be attributed to the ſudden formation and evolution of an elaſtic fluid, but it is remarkable that ſome of the moſt terribly detonating ſubſtances, as fulminating ſilver, produce a very ſmall quantity of gas in proportion to the violence of their exploſion, and when fired in the chamber of a piſtol, propel a ball with a very trifling velocity. The projectile force of an exploſive compound probably depends on the quantity and elaſticity of the gas produced, as gunpowder is ſuperior for this purpoſe to any known ſubſtance, and at the ſame time yields the largeſt proportion of gaſeous fluids; while in the violence of its report an ounce of this ſubſtance inflamed in the open air, is greatly inferior to that produced by even two grains of fulminating ſilver. The ſphere within which detonating bodies act, appears to diminiſh in proportion to the increaſed violence of their exploſion, but in return, the force exerted by them within the ſphere of their action appears to be proportionably augmented.

FULMINATING SILVER. See SILVER.

FUNNEL. } Articles of chemical appa-
FURNACE. } ratus: for an account of which ſee the Appendix.

FUSIBLE METAL. See BISMUTH.

FUSIBLE SALT OF URINE. See PHOSPHAT *of Soda and Ammonia.*

FUSTIC. For the uſe of this dyeing drug ſee the article DYEING, p. 377.

[a] Higgins's Minutes, p. 318.

G

GADOLINITE.[a] The colour of this mineral is deep greeniſh-black. When pulverized it becomes of a greyiſh green. It occurs in maſs, in nodules, or coarſely diſſeminated. Externally it is rifty and glimmering, and is often covered with a whitiſh coating; internally it is ſhining with a vitreous luſtre. Its fracture is compact conchoidal, paſſing ſometimes into ſlaty and uneven. It breaks into ſharp edged indeterminately angular fragments. It is opake, but in very thin ſhivers is tranſparent at the edges. It does not give fire with ſteel, though it is too hard to be ſcratched by a common knife. Sp. gr. 4.23. It is attractable by the magnet, and when mixed with fluor ſpar and fuſed affords a metallic button, amounting to about 8 per cent. alſo attractable by the magnet. When ignited it becomes of a yellowiſh brown colour, and exhibits a ſlaty texture, and loſes about 1 per cent. of its weight.

The above is Klaproth's deſcription, and is taken from the ſpecimens which he analyzed. The gadolinite deſcribed by Hauy and Brochant, and analyzed by Vauquelin differs from the preceding in the following particulars.

Its colour is pure black paſſing into browniſh-black; it is hard enough to ſcratch quartz, though ſlightly. Sp. gr. 4.04. It decrepitates before the blowpipe, becomes of a reddiſh-white colour, and loſes by ignition nearly 10 per cent.

This mineral has hitherto been found only in Sweden; at Ytterby in Roſlagen, and Kimiſt in Finland, forming veins in a granitic rock. It was firſt diſcovered by Arrhenius, and deſcribed in Crell's Chemical Annals by Geyer in 1788. It was analyzed by Gadolin in 1794, and was found to contain a new earth, which has been called from the place whence it is procured, Yttria. Ekeberg, Vauquelin, and Klaproth ſucceſſively confirmed the diſcovery of Gadolin, though with ſome modifications: laſtly, Ekeberg made a new analyſis of this mineral, differing in many reſpects from the former one.

Where the analyſes of a mineral by three ſuch able chemiſts as theſe juſt mentioned are found to differ from each other very materially, it is an intereſting employment, and one of ſome importance to the credibility of chemical analyſis in general, to endeavour to aſcertain the cauſe of theſe diſcrepancies, the reader therefore will, we truſt, excuſe us for treating this ſubject with ſome minuteneſs.

The firſt analyſis of this mineral is that made by Profeſſor Gadolin, by which he found its conſtituent parts to be

Silex - - - -	31
Alumine - - -	19
Oxyd of iron - -	12
A new earth - -	38
	100

This analyſis though very incorrect, deſerves to be quoted, as it is the firſt that was made of this mineral, and as it eſtabliſhes the claim of the Swediſh profeſſor to the diſcovery of the new earth, now called Yttria. It is unneceſſary, however, to enter into particulars, as the difficulties of the analyſis will be better illuſtrated by an examination of the later analyſes.

Mr. Ekeberg of Upſal was the next who undertook an enquiry into the conſtituent parts of this mineral. For this purpoſe, 1. The levigated foſſil was digeſted with muriatic acid till every thing was taken up except the ſilex; 2. The ſolution was precipitated by cauſtic ammonia, and the precipitate while moiſt was boiled in cauſtic potaſh. 3. The alkaline ſolution was ſuperſaturated by nitric acid, and then the addition of carbonated ammonia threw down the *alumine*. 4. That portion of the precipitate, No. 2. which was inſoluble in potaſh was diſſolved in ſulphuric acid, and after being boiled down to dryneſs was ignited till it acquired a brick-red colour from the decompoſition of the ſulphated iron: being then boiled with water it left behind an *oxyd of iron* which was further edulcorated on the filter. 5. The water of No. 4. being ſlowly evaporated, depoſited cryſtals of ſulphated yttria, and theſe being again diſſolved in water the addition of carbonated ammonia occaſioned a depoſition of *carbonat of yttria*, from which when well waſhed the pure earth was obtained by ignition. By this mode of proceeding Mr. E. obtained from 100 parts of gadolinite

Silex - - - - -	25.
Oxyd of iron - -	18.
Alumine - - -	4.5
Yttria - - - - -	47.5
	95.0

[a] Klaproth, Hauy, Brochant, Jameſon.

M. Klaproth[b] having undertaken the analyſis of gadolinite, began by the following preliminary experiments. 1. 200 grains of this mineral finely pulverized were treated with muriatic acid, which diſſolved the greateſt part of it; the inſoluble reſidue was 49 grs. of ſilex. 2. The muriatic ſolution being evaporated to dryneſs was digeſted with alcohol, by which it was totally diſſolved. 3. To the alcoholic ſolution diluted with water was added cauſtic ammonia, by which the whole of the earth and metallic oxyd was precipitated, as the ſupernatant liquor when poured off was not affected by carbonat of potaſh, even when the two fluids were boiled together. 4. The precipitate No. 3. was diſſolved in ſulphuric acid, evaporated to dryneſs, and ignited for half an hour; being then boiled and waſhed in water 76 grs. of red oxyd of iron remained. 5. The watery liquor was colourleſs and ſweet to the taſte, on the addition of carbonated ammonia a white earth fell down which was rediſſolved by an exceſs of the precipitant. The clear ſolution being then heated in a retort to expel the exceſs of ammonia, a copious white precipitate was depoſited which when ſtrongly ignited acquired an iſabella yellow colour, and weighed 80 grs. 6. The oxyd of iron No. 4. was divided into two equal portions; one half being mixed with linſeed oil was heated in a covered crucible and became obedient to the magnet, but being a ſecond time treated with ſulphuric acid and ignited, yielded by lixiviation a freſh portion of ſulphat of yttria. 7. The other half of the oxyd was digeſted with muriatic acid, and precipitated with cauſtic potaſh: a ſmall portion of the precipitate was rediſſolved by an exceſs of alkali, and this being ſuperſaturated by muriatic acid, precipitated by carbonat of potaſh and again diſſolved in ſulphuric acid, afforded a few cryſtals of alum.

Having aſcertained theſe preliminary facts, the regular analyſis of this mineral was conducted by M. Klaproth in the following manner. 1. Two hundred grains of pure gadolinite in ſelected pieces were ignited in a covered crucible: when cooled they diſplayed a flaty texture, and were become friable; their colour was changed to light yellowiſh brown, and they had loſt one grain of weight. 2. They were then finely pulverized and digeſted in nitro-muriatic acid till the whole had acquired a gelatinous conſiſtence, and appeared to be decompoſed. It was now evaporated to a moderate dryneſs, and again digeſted with hot water ſlightly acidulated with muriatic acid: the inſoluble part when waſhed and ignited weighed 42.5 grs. and was pure *ſilex*. 3. The muriatic ſolution being largely diluted with water was mixed with a little ſoda, and thus perfectly neutralized; ſuccinate of ſoda was then added till no further precipitation took place. This precipitate weighed 62 grs. and was ſuccinat of iron, which being firſt ignited in an open crucible, and then heated with a little linſeed oil in a covered crucible afforded 35 grs. of *black oxyd of iron* attractable by the magnet. 4. The ſolution No. 3. being decompoſed at a boiling temperature by carbonated ſoda produced a white precipitate, weighing 219 grs. after edulcoration and gentle drying, but when expoſed to a ſtrong red heat for half an hour, yielded 121.5 grs. of a pale grey earth. This earth conſiſted of *yttria*, mixed with a ſmall portion of *alumine*, the amount of the latter of which was eſtimated in the following way. 5. A hundred grains of gadolinite being decompoſed by nitro-muriatic acid in the manner juſt mentioned, and the ſilex being ſeparated, the ſolution was precipitated with cauſtic ammonia; and the precipitate when waſhed was introduced while yet moiſt into a ſolution of cauſtic ſoda. After boiling for a time the liquor was poured off from the inſoluble part, and being firſt neutralized by ſulphuric acid carbonat of ſoda was mixed with it, and the whole was boiled. By this method a white precipitate was obtained weighing 6 grs. after ignition. This being again diſſolved in muriatic acid, and ſaturated to exceſs with carbonat of ammonia, left a very ſmall portion undiſſolved: this inſoluble portion being transferred to ſulphuric acid was taken up by it, and yielded with a little potaſh about 5 grs. of alum, indicating half a grain of alumine, or one grain in 200 grs. of the entire mineral. Therefore 100 parts of gadolinite contain

Silex - - -	21.25
Oxyd of iron -	17.5
Yttria - - -	60.25
Alumine - -	0.5
Water - - -	0.5
	100.00

Vauquelin's analyſis of this mineral[c] con-

[b] Analyt Eſſ. p. 45.

[c] An. de Chim. xxxvi. p. 146.

tains the following particulars. One hundred grains of gadolinite being ignited in a platina crucible lose about eight grains, and the colour of the substance becomes of an ochery yellow: but as during this process the iron has become oxydated the real loss of weight exceeds the eight grains by the amount of the oxygen absorbed by the iron, and this being about three grains, the whole loss by ignition must be set down as = 11 grs.

The analysis is thus effected. 1. The gadolinite being ground to a fine powder is digested with diluted nitric acid, and evaporated to dryness, taking care to increase the heat towards the end of the process, in order to ensure the complete oxydation of the iron. 2. The whole is now to be redissolved in water, and as the solution still contains a little iron this may be got rid of either by again evaporating to dryness and subsequent digestion in water, or by precipitating the iron by a drop or two of ammonia. 3. The solution is now mixed with caustic ammonia as long as any precipitate is produced; and the supernatant liquor and washings of the precipitate being mixed with carbonated potash a little *carbonat of lime* is thrown down. 4. The first precipitate No. 3. is redissolved in nitric acid, and by the cautions and gradual addition of hydro sulphuret of potash the *oxyd of manganese* is separated. 5. The clear liquor now only contains nitrat of *yttria*, from which the earth is procured by caustic ammonia. 6. The insoluble residues No. 2. consist of *silex* and *oxyd of iron*, which are separated by muriatic acid, the earth remaining undissolved.

Another method is, 1. To fuse the mineral with twice its weight of caustic potash, to digest the mass in boiling water, and then separate the liquor while hot from the undissolved portion by the filter. 2. The liquor will be of a fine green colour, indicating the presence of manganese, and by exposure to the air will become colourless, the oxyd of manganese being precipitated in the form of a black powder. 3. The clear liquor is now to be saturated with nitric acid, and the same menstruum very much diluted is to be digested on the insoluble portion No. 1. The two nitrous liquors being mixed together and evaporated to dryness, and redigested in water contain only the nitrats of lime and yttria; while the portion insoluble in nitric acid consists of silex and oxyd of iron, both of which are to be separated in the manner already described. From the results of these processes Vauquelin states the component parts of 100 grs. of gadolinite to be

Silex	25.5
Oxyd of iron	25.
Ditto manganese	2.
Lime	2.
Yttria	35
	89.5
Loss, consisting of water and some carbonic acid	10.5
	100.0

The particulars of the last analysis of gadolinite by M. Ekeberg being locked up in the Swedish language we are obliged to have recourse to a brief abstract published in the Annales de Chimie[d]. From this it appears that M. Ekeberg followed the practice of Klaproth in separating the iron by succinat of soda, that he found no lime nor alumine, but a small portion of glycine: and that 100 parts of the entire mineral contain

Silex	23.
Oxyd of iron	16.5
Glycine	4.5
Yttria	55.5
	99.5
Loss	0.5
	100.0

Notwithstanding the apparent differences in the preceding analyses it is satisfactory to find that most of them may be reconciled, or at least accounted for by a comparison of the different modes of operating adopted by their respective authors.

It is obvious that in M. Ekeberg's first analysis the proportion of iron is stated too high, and that of yttria too low, in consequence of his supposing that the sulphat of yttria is totally undecomposable by a red heat continued long enough to superoxygenate the sulphat of iron, and thus render it insoluble in water: for Klaproth in his preliminary experiments No. 6. has shown that a considerable part of the sulphat of yttria is also decomposed, together with the sulphat of iron. The way in which the proportion of alumine was ascertained is also liable to objection; for not only this earth but also

[d] Tom. xlviii. p. 276.

glycine is ſoluble in cauſtic potaſh, and both are precipitable by carbonated ammonia provided this is not added to exceſs. It is alſo probable that ſimple digeſtion with muriatic acid would not ſeparate the whole of the other earths from the ſilex with which they were at firſt combined; and this ſuſpicion is further confirmed by the reſults obtained by Klaproth, who in his preliminary experiments found that 24.5 per cent. of this mineral was inſoluble by digeſtion with muriatic acid; but in his analyſis, when he uſed nitro-muriatic acid, and evaporated to dryneſs, there remained only 21.25 per cent. of inſoluble matter.

In the analyſis by M. Klaproth the amount of ſilex appears to be deduced in a perfectly unexceptionable manner, as well as that of the alumine; but the very ſame experiment which proves the quantity of this latter earth alſo ſhows the preſence of 5.5 per cent. of glycine; for one of the eſſential characters of this ſubſtance is, to be ſoluble in cauſtic fixed alkali, by which it is diſtinguiſhed from yttria, and another is, to be ſoluble in carbonated ammonia, by which it is diſtinguiſhed from alumine. The oxyd of iron may be conſidered as fairly determined ſince M. Klaproth expreſsly mentions that the muriatic ſolution No. 3. was *largely* diluted with water before the addition of ſuccinat of ſoda: if this had not been the caſe, there might have been a ſlight cauſe of error becauſe ſuccinat of glycine is very ſparingly ſoluble in water, and a ſmall quantity might therefore have fallen down with the ſuccinat of iron.

Vauquelin's experiments clearly ſhow that the ſubſtance which he operated on loſes upwards of 8 per cent. by ignition, and this conſiſts partly of water and partly of carbonic acid. The preſence of manganeſe is also made very manifeſt, eſpecially in the ſecond mode of analyſis, but the ſtatement of its actual amount is not to be depended on, for the hydroſulphuret of potaſh in the firſt analyſis No. 4. even when all poſſible caution is uſed, would be very apt to carry down a little earth along with the manganeſe: and in the ſecond analyſis No. 2. the cauſtic potaſh would diſſolve not only the manganeſe but alſo a little black oxyd of iron, and both would ſpontaneouſly ſeparate from the ſolution by expoſure to air. The experiment indicating the quantity of lime cannot be objected to: but the mode of ſeparating the ſilex, oxyd of iron, and yttria, is very erroneous. In the firſt place nitric acid is by no means ſo active a menſtruum as muriatic acid for theſe kinds of analyſis; and in the next place if ſulphat of yttria is in part decompoſed at a temperature neceſſary to render ſulphat of iron inſoluble, it is extremely probable that the nitrats of yttria and iron ſtand in the ſame mutual relation: we may therefore ſet down the ſilex as ſomewhat exaggerated, the oxyd of iron as greatly ſo, and the yttria as diminiſhed in at leaſt an equal proportion. If however all poſſible allowance is made for the ſources of error which have been juſt pointed out, ſtill the great loſs by ignition, the preſence of manganeſe, which Klaproth expreſsly ſearched for in vain, and the difference in the external character, ſeem to render probable a ſuſpicion that there is a real, though perhaps not amounting to a ſpecific, difference between the ſubſtance analyzed by Vauquelin and the gadolinite examined by Klaproth and Ekeberg. With regard, however, to the abſence of manganeſe from the gadolinite analyzed by Klaproth, it is to be obſerved that this able chemiſt has not particularized the experiments inſtituted by him to prove this point, and that the yttria even when conſidered by him as perfectly pure had a light cream colour, and when combined with ſulphuric acid depoſited cryſtals of a pale amethyſt red, which may poſſibly have been occaſioned by the preſence of magnaneſe, more eſpecially as all the other earths when pure are ſnow-white, and afford colourleſs cryſtals with acids.

The analyſis of gadolinite by Klaproth as fairly deduced from his own experiments would ſtand thus:

Silex - - -	21.25
Oxyd of iron -	17.5
Glycine - -	5.5
Alumine - -	0.5
Yttria with a trace of manganeſe	54.75
Water - - -	0.5
	100.00

and when this is compared with the laſt analyſis of this ſubſtance by Ekeberg the two will be found very nearly to correſpond.

The following are the properties of YTTRIA as far as they have been examined.

Its ſpecific gravity according to Ekeberg is = 4.84, a very remarkable character which has alſo been obſerved by Vauquelin. It is not reducible to the reguline ſtate by heating with

charcoal, it runs during the proceſs into a ſemifuſed maſs, and its ſpecific gravity is ſomewhat increaſed. It is inſipid and inodorous, and inſoluble in water. It is infuſible *per ſe*, but with borax it forms a clear colourleſs glaſs.

It is inſoluble in the fixed alkalies either pure or carbonated, alſo in cauſtic ammonia: but is readily diſſolved by carbonated ammonia. The pure alkalies ſeparate it from all its acid combinations. It is ſoluble in ſulphuric acid, and the ſulphat of yttria thence reſulting cryſtallizes in rhomboids: it has a ſweet ſomewhat aſtringent taſte, is ſoluble in 25 to 30 parts of cold water, and requires nearly the ſame quantity of hot. It is decompoſable by a red heat, the acid being volatilized. The muriatic and nitric acids alſo diſſolve yttria, but the ſalts thence reſulting are not cryſtallizable. Acetic acid forms with yttria a ſalt that cryſtallizes in four ſided priſms. The neutral ſuccinats decompoſe the muriat of yttria, producing ſuccinat of yttria, which is very little ſoluble, and falls down in cryſtalline grains, except a large quantity of water is preſent.

Neutralized muriat of yttria is decompoſable by pruſſiat of potaſh, a pearl-grey powder being precipitated, which however is reſoluble in a ſlight exceſs of muriatic acid. It is alſo decompoſable by pure tan, or by infuſion of galls, but is only rendered turbid by gallic acid.

Oxalic acid and oxalat of ammonia throw down from the ſalts of yttria a white precipitate, which in its appearance and manner of ſubſiding bears a very near reſemblance to muriat of ſilver.

Phoſphoric acid does not decompoſe the ſulphat, nitrat or muriat of yttria, but phoſphat of ſoda occaſions a white flocculent gelatinous precipitate.

The carbonated fixed alkalies decompoſe the ſalts of yttria, and produce a white pulverulent carbonat of yttria, inſoluble in water, and compoſed according to Klaproth of

Yttria - - - -	55
Carbonic acid - -	18
Water - - - -	27
	100

Yttria in its general properties and habitudes with acids bears a conſiderable reſemblance to glycine. It is, however, diſtinguiſhable from this earth by its inſolubility in cauſtic fixed alkali, its being precipitable by pruſſiat of potaſh, and its ſuperior ſpecific gravity.

GALENA. See LEAD *ores of*.

GALL animal. See BILE.

GALL NUT. *Noix de Galle*, Fr. *Gallapfel*, Germ.

Gall-nut is the produce of the prickly-cupped oak (Quercus Cerris *Linn.*) a ſmall timber tree that grows wild in almoſt all the countries bordering upon the Mediterranean, and in ſome of the ſouthern provinces of Germany. This ſubſtance is ſaid to originate from a puncture made by an inſect of the genus cynips, to the young of which, while in their larva ſtate, it ſerves for habitation and food. It is found adhering to the ſoft annual ſhoots of the tree, and in ſhort, in its original ſituation and general appearance is conſidered by naturaliſts as preciſely ſimilar to thoſe excreſcencies on our Engliſh oaks, vulgarly called *oak-apples*. There are two kinds of gall-nut diſtinguiſhed in commerce; the inferior is of a pale brown colour, and about the ſize of a nutmeg, and is procured from Spain, France, and the northern Mediterranean countries; the ſuperior ſort is of a deep olive colour, approaching to black, is ſmaller than the other, and its ſpecific gravity is conſiderably greater: it is produced in Aſia Minor, but more eſpecially in Syria, and is hence called the Aleppo gall, this town being the principal ſeat of the foreign Syrian commerce.

Notwithſtanding however the concurrent teſtimony of naturaliſts as to the original of the gall-nut, any perſon who will give himſelf the trouble to break half a dozen *ſound unperforated* Aleppo galls may readily convince himſelf that this is one of thoſe vulgar errors which are repeated and believed from generation to generation, becauſe in philoſophy and natural hiſtory it is eaſier to believe than to examine.

Gall-nut conſiſts of four parts. The external or *cortical* covering is of a denſe fibrous texture, a pale yellowiſh white colour, is very thin, and ſeparable without much difficulty from the part which it encloſes: to the taſte it is highly aſtringent, with a ſlight, and ſometimes a ſcarcely perceptible bitterneſs: when laid on a red-hot iron it ſmokes and blackens, and finally becomes ignited, but without any flame: the ſmoak is ſlightly pungent, accompanied by a peculiar and indeſcribable odour, which, however, chiefly characterizes the reſinous part of the gall-nut. Immediately beneath the cortical part lies that which, merely from its external appearance, we ſhall call the *reſinous* part, and

which conſtitutes by far the greater portion of the gall-nut: the colour of this is dark yelloviſh brown: it has a fibrous texture, and ſhows a great tendency to a conchoidal fracture: it has a glimmering reſinous luſtre, and is very brittle: it is not only aſtringent to the taſte, but nauſeouſly bitter, and appears almoſt entirely ſoluble in the ſaliva: when laid on a red hot iron it becomes black, and in a ſtate of ſemifuſion, and exhales very copiouſly that peculiar odour which we have already mentioned; in a ſhort time it is ignited, and reduced to aſhes, but without producing any flame. The central cavity of the gall-nut is lined with a very pale yelloviſh brown *ſhell*, adhering pretty firmly to the reſinous part; it is of a fibrous texture, without luſtre; to the taſte it is almoſt wholly inſipid like common ligneous fibre, and, like this, when laid on a red hot iron it burns with a yelloviſh flame and a copious production of very penetrating pyroligneous acid. Within the ſhell is contained the *kernel*, which is a ſmall egg-ſhaped body, ſometimes conſiderably flattened, and a quarter of an inch or more in length: it is of a brown cream colour, and an even very minutely granular fracture like a common hazle nut; it breaks down between the teeth like all the oily farinaceous ſeeds when dried: it is inſipid, but after being chewed leaves a faint ſweetiſh flavour like that of a bad almond: it is often found mouldy, and then is of a bright chocolate colour. When laid on a hot iron it becomes ſomewhat moiſt, and gives out a pungent empyreumatic acid in great quantity, but without flaming, and is probably little elſe than amylaceous fecula. This kernel no doubt it is which invites the depredation of inſects; and in all thoſe gall-nuts the kernels of which have been devoured, may be perceived a ſmall tubular paſſage from the outſide to the centre, and in the place of the kernel is generally left a little web, and ſome minute black grains which probably are the excrements of the inſect. Gall-nuts that are unperforated are ſometimes however found hollow, but this may be inferred to be owing to the deſtruction of the kernel by ſpontaneous decompoſition, on account of the mouldy and diſcoloured ſtate of the remaining ſhell.

No chemical analyſis has been made of any one of the four parts of the gall-nut ſeparated from the reſt, although what we have called the reſinous portion ſeems to be particularly intereſting: the gall-nut in general, however, has been ſubjected to ſeveral curious enquiries by Scheele, Deyeux, Prouſt, Davy, and others, of which the following are the principal reſults.

When bruiſed galls are infuſed in diſtilled water at the temperature of about 60° Fahr. a dark brown fluid is obtained in the ſpace of a few hours; this being poured off and another portion of water being added a ſecond infuſion is procured of a ſomewhat lighter colour than the former; after having thus employed four or five ſeparate parcels of water the ſucceeding infuſions exhibit a yelloviſh green tinge, which by degrees becomes more and more faint, till all that portion of gall-nut ſoluble in this menſtruum at the above temperature is taken up. According to Deyeux [a] it requires 96 quarts of water divided into 20 different macerations to exhauſt all the ſoluble matter of a ſingle pound of galls. The brown infuſion acquires a deep black colour by red ſulphat of iron indicating the preſence of gallic acid, a ſolution of iſinglaſs in water occaſions in it a copious precipitate, indicating tan, and muriat of alumine throws down a precipitate denoting the preſence of extract. This brown infuſion ſeems to be furniſhed almoſt entirely by the reſinous part of the nut. The light green infuſion gives a deep blue precipitate with red ſulphat of iron, but is hardly at all affected by the other two reagents; it appears to contain little elſe than gallat of lime, and is probably furniſhed by the cortical covering of the gall-nut. A few drops of moderately ſtrong ſulphuric or muriatic acid change the green tinge of this infuſion to red, after which the original colour may be reſtored by the addition of an alkali, and deepened if it is added to exceſs. The concentrated nitric and oxygenated muriatic acids deſtroy the colour of the infuſion, nor can it be reſtored by an alkali. By long continued ſlow evaporation the green colour is changed into a dirty yellow, and then neither acids nor alkalies act on it in the ſame manner as before.

The ſtrongeſt brown infuſion that can be made by macerating pounded galls with diſtilled water at 56° Fahr. is of the ſpecific gravity of 1.068, and yields by evaporation a little more than $\frac{1}{9}$ of ſolid matter. [b] The ſolution is nearly tranſparent, of a yelloviſh-brown colour and a ſour and highly aſtringent taſte; it ſtrongly reddens litmus and ſhows other proofs of a diſengaged acid. When ſulphuric acid is poured into the infuſion, a denſe white precipitate is

[a] An. de Chim. xviii. p. 11.

[b] Davy in Phil. Tranſ. for 1803.

thrown down, and the ſupernatant liquor becomes of a deeper colour than before: it is not however by this proceſs freed entirely from any of its ingredients, ſince it ſtill continues to give a deep black with the oxygenated ſalts of iron, and to afford a precipitate with gelatin. The ſulphuric precipitate when ſeparated by the filter, ſlightly reddens vegetable blues, yields gallic acid by diſtillation, and when diſſolved in warm water gives a copious precipitate with iſinglaſs. Muriatic acid produces a ſimilar effect on the infuſion to that of ſulphuric acid. Strong nitric acid when firſt added to the infuſion renders it turbid, but the ſeparating matter is ſoon diſſolved with efferveſcence and the liquor becomes clear and of an orange colour: the exceſs of acid being ſaturated by an alkali, both the tan and gallic acid of the infuſion are found to be deſtroyed, for no precipitate is occaſioned by a ſolution of gelatin, nor any change of colour by red ſulphat of iron. By evaporation, a ſoft yellowiſh brown ſubſtance is procured, which from its decompoſing nitro-muriat of tin and nitrat of alumine, appears to be a kind of extract. If a very diluted nitric acid is employed, its effects on the infuſion are ſimilar to thoſe of the ſulphuric and muriatic acids.

A ſolution of either of the fixed alkalies in a perfectly cauſtic ſtate occaſions a temporary turbidneſs in the infuſion and changes its colour to brown-red: in this ſtate it gives no precipitate with gelatin till the addition of an acid, when a copious ſediment is produced. Cauſtic ammonia at a moderate temperature has the ſame effect as fixed alkali, but when the mixture is expoſed to the heat of boiling water, part of the ammonia is volatilized and the remainder reacts on the tan and gallic acid of the infuſion, converting them almoſt entirely into a ſubſtance precipitable by muriat of tin and the aluminous ſalts.

If inſtead of a perfectly cauſtic fixed alkali, one that is only partially ſo be employed, a precipitate is thrown down from the infuſion, the quantity of which varies in proportion to that of the carbonic acid united with the alkali. That the formation of this precipitate depends on the preſence of carbonic acid is manifeſt from this circumſtance, that if carbonic acid gas is paſſed through the reſidual clear liquor, conſiſting of cauſtic alkali and infuſion of galls, an immediate precipitate is occaſioned, which exhibits the ſame properties as that produced by carbonated alkali in the infuſion. The following are the characters of the precipitate: it has not the aſtringent taſte of uncombined tan; it is but imperfectly ſoluble in cold water or alcohol; when digeſted in a large quantity of hot water it is ſeparated into an inſoluble and a ſoluble part; the former of theſe is not acted on by alcohol, it is partially ſoluble in muriatic acid, and the ſolution precipitates gelatin and the ſalts of iron; when incinerated it affords a conſiderable proportion of lime but no alkali; hence it appears to be a compound of lime, gallic acid, tan, and perhaps a little extract: the part ſoluble in hot water is incapable of precipitating gelatin till the alkali is ſaturated by an acid, and when incinerated it yields carbonated alkali.

The alkaline earths when added in ſubſtance or in ſolution to the brown infuſion of galls, combine with the whole of the tan and throw down a green precipitate: the ſupernatant liquor is alſo of a green colour, which becomes more intenſe by expoſure to the air: it is made turbid by ſulphuric acid and gives a black precipitate with the ſalts of iron, and conſiſts of gallic acid and probably ſome extract combined with part of the alkaline earth. The green precipitate by repeated waſhing with water gives out nearly the whole of its gallic acid, and the reſidue is little elſe than tan with the alkaline earth. The artificial carbonats of theſe earths produce the ſame effect as the pure earths.

If alumine is boiled with the infuſion it becomes of a yellowiſh grey tinge and combines with the whole of the tan and extract, and nearly the whole of the gallic acid; the ſupernatant liquor being clear and colourleſs and giving a very faint purple with red ſulphat of iron: if only a very ſmall proportion of alumine be employed, the liquor conſiſts of gallat of alumine with exceſs of acid.

The perfect oxyds of tin and zinc prepared with nitric acid, when boiled with the infuſion become of a dull yellow colour and reduce the ſupernatant fluid to mere water: the yellow oxyds are ſoluble in muriatic acid, and then give a copious precipitate with gelatin and a denſe black with ſalts of iron.

The compound earthy and alkaline ſalts alſo decompoſe the infuſion of galls, but the precipitate is not pure tan as has been ſuppoſed, for it contains beſides ſome gallic acid, extract, and the precipitant ſalt. The ſame may be obſerved of moſt of the metallic ſalts.

When the brown infuſion is expoſed to gentle evaporation, it firſt becomes turbid by the depoſition of part of its extractive matter, and at length acquires the conſiſtence and appearance

of a tough brown extract, which while it is warm may be moulded like Chio turpentine, but when it becomes cold is dry and hard and very eaſily pulverizable. By expoſure in cloſe veſſels to a heat ſuperior to that of boiling water, the maſs firſt ſoftens, then ſwells and gives out a prodigious quantity of carbonic acid; there ſublimes at the ſame time a white ſalt in needles and ſcales, which is pure gallic acid: ſoon after a fluid ariſes in which the gallic acid diſſolves, and this is ſucceeded by a thick black oil; at this period the gas, which hitherto has been carbonic acid, becomes inflammable, and ſo continues till nothing but a dry coal is left in the retort.

An exact analyſis of galls is for the preſent at leaſt impracticable, ſince we are not acquainted with any reagents that will ſeparate any of its component parts unmixed with the others: upon the whole perhaps the beſt mode of proceeding is as follows. Take any quantity of galls and reduce them to powder, then by means of repeated infuſions with water at a temperature leſs than that of ebullition, extract every thing that is ſoluble. The reſidue being thoroughly dried will indicate with conſiderable exactneſs, by means of its loſs of weight, the amount of ſoluble matter. All the different infuſions being mixed together are to be evaporated at a very gentle heat to a ſmall bulk, during which ſome reddiſh-brown extract will be depoſited and muſt be carefully ſeparated and dried; the reſidual fluid by ſubſequent evaporation is to be brought to a ſolid ſtate and then digeſted in pure alcohol, by which the tan, gallic acid, and extract will be taken up, while the mucilage mixed with ſome impurities will remain inſoluble and may thus be ſeparated. The alcoholic ſolution being again evaporated, the reſidue is to be diſſolved in water, and a ſtrong ſolution of iſinglaſs is to be poured in as long as any precipitation takes place: this precipitate when well waſhed conſiſts of tan, and gelatin with a very little extract and gallic acid, and contains about 46 per cent. of tan. The reſt of the ſolution is gallat of lime with exceſs of acid, and a little extract.

According to Davy, 500 grains of good Aleppo galls contain 185 grains of matter ſoluble in water, and this conſiſts of

	grains.
Tan	130
Mucilage and extract depoſited during evaporation	12
Gallic acid with a little extract	31
Lime and ſaline matter	12

For further particulars concerning gall-nut ſee Gallic acid, Ink, and Tanning.

The uſes of this ſubſtance are very important. It is employed largely in dyeing not only blacks and various kindred colours, but is alſo an eſſential ingredient in the compoſition of the fineſt madder reds: it is a neceſſary part of all the black writing inks: it is employed in the laboratory as a uſeful teſt for the ſalts of iron, and is occaſionally uſed in medicine.

GALLIC ACID. *Acide Gallique*, Fr. *Galluſſaure*, *Gallapfelſaure*, Germ.

The exiſtence of an uncombined acid in galls and in various other aſtringent vegetable ſubſtances, was ſuſpected by Macquer, Lewis, Monnet, and other able chemiſts, but was not demonſtrated till the year 1772, when Morveau and the other Dijon academicians took the ſubject in hand. They found that the infuſion of galls changed vegetable blues to red, was capable of decompoſing the alkaline hydroſulphurets, of diſſolving metallic iron, and of decompoſing and precipitating the ſolutions of ſeveral metallic ſalts. The ſubject remained in this ſtate till 1780, when Scheele put the matter beyond doubt by publiſhing a method of ſeparating the acid from the other ingredients of the gall-nut. This acid obtained the name of the gallic from the ſubſtance which yields it the moſt eaſily and in the greateſt plenty, and has ever ſince taken its place among the other native vegetable acids.

The method employed by Scheele to obtain the gallic acid is the following. Take any quantity of Aleppo galls, and having reduced them to a coarſe powder digeſt it in three or four ſucceſſive portions of ſcalding water, by which almoſt all the ſoluble part will be extracted; then add together all the infuſions, and a brown turbid liquor will be obtained, intenſely aſtringent and ſomewhat acid: put the liquor into a large uncovered baſon and ſet it by in a warm room for two or three months: in a few days a covering of mould will appear on the ſurface, which muſt be occaſionally broken and ſtirred into the liquor. In proportion as the proceſs of moulding goes on, the aſtringent taſte of the fluid becomes weaker and the acid taſte increaſes, at the ſame time a dirty brown ſediment mixed with cryſtalline grains is depoſited. When the whole is evaporated to dryneſs or nearly ſo, the remainder is to be digeſted in about an equal weight of hot rectified alcohol, and the liquor is to be paſſed as haſtily as poſſible through a filter. The undiſſolved reſidue is to be a ſecond time digeſted in half the quan-

tity of the alcohol uſed at firſt, and this ſecond ſolution after filtration is to be added to the firſt. The liquor as it cools will depoſit ſome brown cryſtalline grains, and freſh portions may be procured by ſucceſſive evaporation and cooling. Theſe impure cryſtals being a ſecond time diſſolved in as ſmall a quantity as poſſible of hot alcohol, will ſeparate by cooling in the form of ſmall grains of a browniſh yellow colour, and in this ſtate form the gallic acid of Scheele. But the acid thus prepared is by no means pure, it not only contains a little extract by which it is coloured but (what has not been adverted to) it alſo contains lime, and that in no ſmall quantity; for when diſſolved in water and neutralized by carbonated ſoda, a coloured precipitate falls down, and the ſupernatant liquor after a ſhort expoſure to the air becomes of a deep green colour. In order therefore to purify this acid the beſt method is to rub it up with an equal weight of dry charcoal, and then heat it in a very ſhort necked retort with an attached receiver: the heat muſt be juſt ſufficient to diſengage white fumes from the mixture and no more; theſe fumes paſſing into the receiver will concrete there and line the whole inſide of the veſſel with long ſilky cryſtals of a ſilvery whiteneſs, which are pure gallic acid. The loſs of weight in this proceſs is conſiderable, but not more than might be expected when it is remembered that the produce is only the exceſs of acid beyond what is neceſſary to neutralize the lime which the native acid contains. Inſtead of employing the acid of Scheele for this purpoſe the gall-nut in ſubſtance may be ſubjected to dry diſtillation; there firſt ariſes a watery acid liquor, then white cryſtals of gallic acid, which are ſoon however ſucceeded by a brown oil which ſoils and diſſolves them if the proceſs is not ſtopped in time. Probably the addition of dry pounded charcoal would detain the oil, and thus both facilitate the operation and augment the produce.

A new method of obtaining pure gallic acid has been propoſed by M. Fiedler. [a] It conſiſts in digeſting the watery infuſion of galls with alumine, and procuring from the clear liquor by ſlow evaporation needle-form cryſtals. But theſe are probably not pure gallic acid but only acidulous gallat of alumine.

Pure gallic acid is in the form of white brilliant needle-form cryſtals, of a ſour pungent taſte and ſomewhat auſtere. At a heat ſomewhat exceeding that of boiling water it becomes fluid and of a ſlightly brown colour, thus indicating a partial decompoſition; at the ſame time it gives out white vapours, which have a faint ſub-aromatic odour and concrete by cooling into white cryſtals as at firſt. While ſolid it is not ſenſibly acted on by the air. It requires about 24 parts of cold and three of hot water for its ſolution. It powerfully reddens vegetable blues and exhibits the uſual characters of an acid. When diſſolved in water it ſhows a ſtrong tendency to decompoſition, the ſolution becomes coloured, as alſo are the cryſtals which it yields by evaporation. Cold alcohol will diſſolve about a fourth of its weight of this acid, and at a boiling temperature will take up full its own weight.

By concentrated ſulphuric acid it is charred and decompoſed: ſtrong nitric acid converts it into a mixture of malic and oxalic acids. Oxymuriatic acid alſo decompoſes it, but the mutual action of theſe two ſubſtances has not been ſufficiently examined. The other acids diſſolve gallic acid, but without occaſioning any immediate change.

It combines with the alkalies and alkaline earths, forming ſalts of little ſolubility, but the properties of which have not been inveſtigated.

In conſequence of the ready decompoſition of this acid and the large proportion of carbon that it contains, it precipitates gold, ſilver, mercury, copper, biſmuth and iron from all their acid combinations, reducing the two firſt in part to the metallic ſtate. It appears incapable of decompoſing the ſalts of platina, zinc, tin, cobalt, and manganeſe. The oxygenated ſalts of iron are thrown down by it, of a deep blue colour approaching to black, and this is its moſt characteriſtic property. It is not uſed in its pure ſtate, but as a component part of GALLS and other aſtringent vegetables. It is applied to a variety of important purpoſes, for which ſee eſpecially the articles DYEING and INK.

GAMBOGE. *Cambogia Gutta.*

The gum-reſin, commonly called gamboge, is the produce of a middling-ſized tree that grows wild in Ceylon, Siam, and Cochin-China, and is called by botaniſts Stalagmitis Gambogioides. The Siameſe gamboge is in ſmall tears formed by the concretion of the drops of juice as they fall from the leaf-ſtalks, and young ſhoots when they are broken off from the tree. In Ceylon the juice is procured by deep inciſions in the bark, and is afterwards inſpiſſated by the heat of the ſun and moulded into cakes or rolls. When pure, its colour is a deep rather dull orange, its fracture is conchoidal and ſomewhat

[a] Van Mons's Journ. de Chim. i. p. 85. or Nicholſon's Journ. 8vo. i. p 236.

ſhining. It has no ſmell and very little taſte, but when kept in the mouth for ſome time it gives a ſlight impreſſion of acrimony. If applied to the flame of a candle it melts and blazes, throwing out ſparks and emitting a denſe black ſmoak.

Gamboge is not properly ſoluble though extremely diffuſible in water, with which it forms an opake yellow-coloured infuſion: by paſſing the liquor through a filter ſome reſin is detained, but the fluid ſtill continues coloured and turbid. Alcohol is a more effectual ſolvent for this ſubſtance, which it takes up in large quantity and forms a clear gold-coloured fluid: on the addition of water the alcoholic ſolution becomes turbid like the watery infuſion. Of 16 ounces of gamboge, water, according to Neumann, will take up 13 ounces, and of the reſidue 2 ounces are ſoluble in alcohol: of an equal quantity alcohol will firſt diſſolve 14 ounces, and of the reſidue one ounce is ſoluble in water; the inſoluble matter in both caſes amounting to $\frac{1}{16}$ of the whole. Both the fixed alkalies and ammonia effect almoſt a total ſolution of gamboge, producing a clear liquor of a deep and rich red brown colour, and the reſiduum being pure gum is entirely ſoluble in water. The addition of an acid to the alkaline ſolution throws down a copious yellow precipitate, which when dried preſents an earthy fracture, is difficultly combuſtible and does not melt like the pure reſin.

Gamboge, beſides its medical application, is extenſively uſed as a water colour, and its tincture in alcohol is one of the ingredients of the gold coloured lacquer with which moſt of the ſmaller articles that are made of braſs are overlaid: it is alſo employed by the inlayer and cabinet-maker to ſtain white woods in imitation of box, &c. *See the article* VARNISH.

GARNET.[a] *Grenat*, Fr. *Granat*, Germ. The colour of garnet is blood or cherry red; when mixed with blue it paſſes into crimſon and violet red, and when tinged with yellow into hyacinth red; it is alſo met with of a reddiſh brown colour, liver brown and black, alſo greeniſh-yellow, greeniſh-brown, and greeniſh-black. It occurs in maſs, diſſeminated, in angular fragments, or cryſtallized. Its primitive figure is the rhomboidal dodecahedron, which when ſomewhat lengthened preſents the appearance of a ſhort ſix-ſided priſm, the faces of which are parallelograms terminated by trihedral ſummits with rhomboidal faces. Sometimes the original faces of the dodecahedron entirely diſappear, and the reſult is a ſolid bounded by 24 equal and ſimilar trapeziums. Sometimes all the ſides of the primitive dodecahedron are replaced by lengthened hexagons, whence reſults a ſolid bounded by 12 rhombs and 24 hexagons. Other more complicated figures, but which cannot be rendered intelligible by mere deſcription, originate from the mixture of the two preceding modifications. The ſize of the cryſtals is ſubject to great variations; ſome are no larger than a pin's head, while others are four inches or more in diameter. The external luſtre is caſual but generally gliſtening; the internal luſtre is bright-ſhining, vitreous. Its fracture is perfectly conchoidal paſſing into imperfectly conchoidal, coarſe grained uneven, or ſplintery. Its fragments are indeterminately angular and ſharp-edged. It ſometimes occurs in granular or lamellar diſtinct concretions. It varies from tranſparent to tranſlucent on the edges. Its hardneſs is ſuperior to that of quartz. Sp. gr. 3.7 to 4.2.

It is often magnetic, and is fuſible without much difficulty before the blowpipe into a black enamel. When ſtrongly heated in a charcoal crucible it affords a grey duſky glaſs full of grains of iron, often amounting to 10 or 12 per cent.

This mineral has been repeatedly analyzed by Klaproth, Vauquelin, and other able chemiſts, but without much agreement in the reſults; and as in general the ſame method of analyſis has been adopted, the remarkable differences which have occurred can only be attributed to a real variation in its compoſition: they all agree however that it contains a large proportion of iron, and poſſibly this ingredient may be the one which principally influences its cryſtallization.

The Bohemian garnet has been analyſed by Klaproth[b] and Vauquelin,[c] with the following reſults.

	Klapr.		Vauq.
Oxyd of iron	16.5	—	41.
Oxyd of manganeſe	0.25	—	0.
Silex	40.	—	36.
Alumine	28.5	—	22.
Lime	3.5	—	3.
Magneſia	10.	—	0.
	98.75		102.

The Sirian garnet, according to Klaproth, contains

[a] Emmerling, Hauy, Brochant, Jameſon.
[b] Analyt. Eſs. 1. p. 335.
[c] Journ. des Mines, No. 44. p. 571.

Oxyd of iron - - -	36.
Oxyd of manganeſe -	0.25
Silex - - - - - - -	35.75
Alumine - - - - - -	27.25
	99.25

Beſides the above the following analyſes of garnets have been made by Vauquelin.

	Black G. from Pic d'Ereſſids.	Red G. from ditto.	Yellowiſh amorph. G. from Corſica.
Oxyd of iron	16.	17.	10.
Silex - -	43.	52.	38.
Alumine -	16.	20.	20.
Lime - -	20.	7.7	31.
	95.	96.7	99.

The moſt beautiful and valuable garnets are the oriental. They come principally from Pegu; and the town of Sirian having been formerly the chief mart for them, they are hence by corruption known among lapidaries by the appellation Syrian garnets. They appear to be the *Carbuncle* of the ancients: their colour is crimſon verging into a very red violet; they are tranſparent and have a conchoidal fracture: of their geological ſituation we are entirely ignorant.

Next in eſtimation to the oriental is the Bohemian garnet (Pyrop of Werner). It is met with in the Mittelgebirge of Bohemia and in Saxony: its colour is blood-red verging into yellow: it never occurs cryſtallized but only in rounded and angular grains: it is tranſparent; its fracture is conchoidal. It occurs in floetz-trap and in alluvial land, formed by the decompoſition of this claſs of mountains; it is alſo met with in ſerpentine.

Common garnet occurs almoſt always in primitive rocks, eſpecially in micaceous ſchiſtus, chloritic ſlate and ſerpentine: it is ſometimes ſo abundant as to conſtitute the principal part of the rocky maſs in which it is found, which is then an excellent flux for iron ores on account of its fuſibility and the large quantity of this metal which it contains.

The Oriental and Bohemian garnets when cut and poliſhed are very beautiful, and were formerly (particularly the firſt) in high eſtimation, but by the caprice of faſhion their employment and conſequently their value has of late very much declined.

GARNET (black). See MELANITE.

GARNET (white). See LEUCITE.

GAS. The term gas, in chemiſtry ſynonimous with *air*, is employed to ſignify any inviſible elaſtic aeriform fluid, permanent at the common temperature of the atmoſphere, and (with the ſingle exception of the oxymuriatic acid gas) not condenſible by any known degree of cold natural or artificial. The diſcovery of the exiſtence and properties of the gaſſes is the peculiar ſtrength and boaſt of modern chemiſtry, and in fact this branch of the ſcience may be ſaid to be created by the multiplied and ingenious labours of chemiſts ſtill living or lately dead, ſuch as Prieſtley, Scheele, Cavendiſh, Lavoiſier, Berthollet, and others.

The chemical deſcription of the various gaſſes will be found in their reſpective places, but a ſummary view of them, and ſome of their characteriſtic properties may be given here, together with ſome other general properties, and in particular the methods employed in analyſis of eſtimating truly their actual quantities, in which more precautions are required than in examining any other claſs of natural bodies.

Strictly ſpeaking, every gas, however ſimple in its nature, is a compound of the baſis of the gas, and of that additional quantity of caloric which is required to enable it to aſſume the gaſſeous form, and it is ſometimes of conſequence to conſider the latter as diſtinct from that other portion of caloric which muſt of courſe be combined with the baſis without inducing any change of form.

Thus muriatic acid gas is compoſed of the hitherto undecompoſed ſubſtance of muriatic acid, (which, like every other body in nature, has its natural inherent portion of caloric,) and alſo of that additional quantity of caloric which conſtitutes it a gas. Hence when this gas is paſſed through water, the acid combines with it, loſes its gaſſeous form and becomes liquid, and the caloric thereby ſet at liberty very ſenſibly raiſes the temperature of the water.

It is therefore an inaccuracy of terms though very commonly uſed to ſpeak of the combinations of gaſſeous bodies with ſolids or fluids inſtead of the *baſes* of theſe gaſſes, as where a metal is ſaid to be oxidated by union with oxygen *gas*, inſtead of *oxygen* the baſis of this gas; or where water is ſaid to hold in ſolution carbonic acid *gas* inſtead of carbonic acid. This inaccuracy particularly ariſes from the circumſtance that we can never exhibit theſe ſubſtances, ſuch as oxygen, hydrogen, or azot, in any form more ſimple than that of a gas, in which is combined only with an exceſs of caloric.

The following are the gaſſes at preſent known, with ſome of the leading characters by which they are diſtinguiſhed in analyſis.

Oxygen Gas is ſparingly abſorbed by water, ſupports flame and combuſtion in an eminent degree, is analyzed by nitrous gas, which it converts totally into nitric acid; is abſorbed by the combuſtion of phoſphorus, and by the ſulphurets.

Azotic Gas is hardly abſorbed by water, extinguiſhes flame, diſſolves phoſphorus, becoming thereby enlarged about $\frac{1}{20}$ of its bulk, and then is luminous on the admiſſion of common air or oxygen—when combined with oxygen by the electric ſpark produces nitric acid.

Carbonic Acid Gas is readily abſorbed by about its own bulk of water, and in much greater quantity by lime, barytic, or ſtrontian water, or by all the alkalies when pure or only partially carbonated—gives a white precipitate with the ſolutions of the above-mentioned earths, which it rediſſolves if it is in exceſs, and which is ſoluble in any other acid with effervescence.

Carbonous Oxyd Gas is ſcarcely abſorbed by water, is but little lighter than common air, burns in air with a large white flame, and produces by its combuſtion only carbonic acid gas.

Hydrogen Gas is ſcarcely abſorbed by water, is remarkably light, when kindled burns gradually at the point of contact with common air or oxygen with a faint blue flame without ſmoke; or when previouſly mixed with common air or ſtill more with oxygen, and kindled, burns inſtantly with a violent exploſion, and in both caſes with the production of much moiſture—diſſolves ſulphur, phoſphorus, carbon, and ſome of the metals, forming gaſſes, which partake of the properties of each of their conſtituents, ſuch as,

Sulphuretted Hydrogen Gas, which has a ſtrong and fetid ſmell, is readily abſorbed by water, burns with a greeniſh-blue flame, readily blackens the colourleſs ſolutions or white oxyds of many metals, particularly lead, ſilver, mercury, iron, and biſmuth, when in ſolution with water is decompoſed by nitric acid and depoſits its ſulphur.

Carburetted Hydrogen Gas has a ſtrong peculiar ſmell, is lighter than common air, little abſorbed by water, burns in air with a white-blue flame and much ſmoke, and the production both of carbonic acid and water.

Olefiant Gas reſembles the latter in many of its properties, but is diſtinguiſhed by generating an oil when mixed with oxymuriatic acid gas.

Arſenicated Hydrogen Gas reſembles pure hydrogen in moſt of its properties, but has a peculiar and moſt offenſive ſmell, and depoſits arſenic by ſtanding, and produces arſenic acid by combuſtion with oxymuriatic acid.

Phoſphuretted Hydrogen Gas is abſorbed by water, has a fetid and characteriſtic ſmell, burns ſpontaneouſly with a ſlight exploſion at the common temperature, as ſoon as in contact with oxygen or common air.

Ammoniacal Gas is abſorbed inſtantly and abundantly by water and moſt other fluids, has a peculiar and moſt pungent ſmell, forms neutral ammoniacal ſalts with all the acids, produces denſe white fumes around any ſubſtance moiſtened with muriatic acid, or particularly when mixed with muriatic acid gas.

Sulphureous Acid Gas has the peculiar ſmell of burning ſulphur, is abſorbed inſtantly and abundantly by water, firſt reddens and then deſtroys many vegetable colours, and diſſolved in water forms the liquid ſulphureous acid.

Muriatic Acid Gas, though inviſible by itſelf, forms white vapours when in contact with air, has a pungent ſmell and excites violent coughing, is copiouſly abſorbed by water, giving out much ſenſible heat thereby, and then forms the common liquid muriatic acid, gives denſe white fumes with ammoniacal gas, or the mere proximity of liquid ammonia.

Oxymuriatic Acid Gas has a very peculiar and very ſuffocating ſmell, is abſorbed by water in a moderate degree, and when to ſuperſaturation, cryſtallizes in part on cooling, in thin plates; when unmixed with muriatic gas it deſtroys vegetable colours without previouſly reddening them, ignites ſpontaneouſly many of the metals and metallic ſulphurets, ſuch as arſenic, antimony, orpiment, and zinc, when added to it in fine powder; diſſolved in water it forms a liquid of an acerb but not acid taſte which acts on gold and platina.

Fluoric Acid Gas reſembles the muriatic but gives a precipitate with lime-water, and when prepared in a glaſs veſſel corrodes it, and, being then received in water, is copiouſly abſorbed by it, each bubble leaving a ſingular depoſition of a ſiliceous film in delicate cylindrical tubes.

Nitrous Gas is ſcarcely at all abſorbed by water, but when ſtanding over this fluid gives copious red fumes, on admitting common air, and eſpecially oxygen gas, and is by the latter totally converted into nitric acid which is then abſorbed by the water. Nitrous gas is copiouſly abſorbed by the green ſulphat or muriat of iron, producing an olive-brown liquor which immediately abſorbs oxygen from any air with which it is mixed.

Nitrous Oxyd Gas reſembles oxygen in eminently ſupporting and encreaſing combuſtion in moſt caſes, but extinguiſhes ſulphur when in

feeble combuſtion; is abſorbed in a conſiderable proportion by water, and undergoes no diminution when mixed with nitrous gas.

To this liſt of the known gaſſes ſeveral modifications of ſome of the ſpecies might perhaps be added, particularly thoſe in which ether enters as a conſtituent part, ſuch as the etherized nitrous gas and others. It is ſtill not quite determined whether *atmoſpheric air* ſhould be conſidered as a peculiar chemical compound, or a ſimple mixture, and therefore imitable by the mere combination of azot oxygen and carbonic acid in the due proportions.

* * *

The abſorption of the different gaſſes by water is attended with ſome circumſtances worthy of remark. With the eaſily abſorbable gaſſes the abſorption is much affected both by the purity of the air employed, and by its actual quantity proportional to that of the water. Thus according to Mr. W. Henry's experiments, [a] if 20 meaſures of carbonic acid be agitated with 10 of water at 55° temperature, at leaſt 10 meaſures will be abſorbed, but if the 20 meaſures be previouſly mixed with 10 of common air, only 6 will be abſorbed. On the other hand water agitated with twice its bulk of carbonic acid gas, will (other things being alike) take up more of the gas than with a leſs quantity, though ſtill more than will faturate the water. The reaſon of theſe two facts appears to be the affinity which exiſts between carbonic acid gas and common air, and which oppoſes the abſorbing action of water, ſince this fluid will always abſorb the carbonic acid in preference to the common air, and in ſo doing therefore will break the union between the two; and indeed when the water previouſly contains common air, the act of abſorption of carbonic acid will expell this common air by ſuperior affinity. Hence the well-known law of affinity comes here into action, namely, that the decompoſition of two bodies by the ſuperior affinity of a third, is conſtantly becoming more and more difficult as the relative proportion of the two firſt becomes more unequal, and often ceaſes altogether before the decompoſition is compleat. Of this there are numerous inſtances in chemiſtry, that is, where a large proportional maſs of one ſubſtance will protect a ſmall portion of another with which it is united, from the decompoſing action of a third, however ſuperior its real chemical affinity may be. Therefore in the above inſtance common air adheres to carbonic acid gas by a conſiderable affinity, which the ſuperior affinity of water can break only partially, and there is a certain point in which the proportion of the common air is ſo great compared with the carbonic acid, as entirely to prevent the further ſeparation of the two by the abſorbing power of water. The addition of a quantity of common air to the carbonic acid will therefore obviouſly diminiſh the abſorption of the latter; and on the other hand a large bulk of carbonic acid gas (which always contains ſome little impurity of common air) will afford a larger abſorption to the water than a ſmaller bulk, as the mixed gaſſes can in the former inſtance ſpare a larger quantity of pure carbonic acid before the mixed reſidue arrives at the undecompoſable proportions, than in the latter. This counteracting affinity of carbonic acid gas and common air, is ſtrikingly illuſtrated by an obſervation of Dr. Brownrigg, who obſerves with ſome ſurprize that though the natural Spa water (which is chiefly a ſtrong ſolution of carbonic acid in water) violently bubbles and loſes its condenſed carbonic acid when in free contact with the atmoſphere, this is not merely owing to the removal of mechanical preſſure from the ſurface of the water (either naturally when the ſpring burſts out into day, or artificially, by drawing the cork of the bottle in which it is confined) ſince when an empty bladder quite air-tight is attached to a bottle containing the water, no gas flies up into the bladder though all mechanical preſſure is removed by this contrivance. It is therefore the contact of atmoſpherical air that cauſes the eſcape of the carbonic acid, owing to the ſtrong affinity exiſting between the two gaſſes, and as the bulk of the atmoſphere is immenſe, the relative proportions between it and the carbonic acid continue the moſt favourable for the ſtrongeſt affinity, both as to the comparative bulk and compoſition of the atmoſphere.

Temperature alſo much affects the abſorption of gaſſes by water, this being the greateſt when the temperature is the loweſt, as would indeed be expected owing to the encreaſed elaſticity, and therefore inaptitude to abſorption, which is given to gaſſes by adding caloric. At a heat even inferior to boiling no gas can be combined with water, but all already combined are expelled, a minute portion excepted, which no known means can entirely remove, but is perceptible by its effects. The gas is thus extricated from any mineral water to be examined ſimply by boiling the water for about a quarter of an hour and carefully collecting the aeriform products.

Preſſure is another circumſtance that affects

[a] Phil. Tranſ. vol. 89.

the abſorption of gaſſes. Mr. Henry found by ſufficiently accurate experiments that under equal circumſtances of temperature, water takes up in all caſes the ſame volume of condenſed gas as of gas under ordinary preſſure. Hence as the volume of any gas is ſimply in inverſe proportion to the compreſſing force, the quantity abſorbable under any circumſtances of preſſure is readily known from the reſult of experiments made under any other preſſure.

Thus a preſſure equal to two atmoſpheres, or about 58 inches of mercury, on a quantity of gas, will cauſe juſt twice as much in weight to be abſorbed by water as under ordinary preſſure, and hence the great importance of machinery for giving preſſure, in the different apparatus employed to make the artificial mineral waters.

We may add to this part of the ſubject the reſults of Mr. Henry's experiments on the abſorption of many of the gaſſes.

One hundred cubic inches of water abſorb, of

	Temperature.	*cub. inch.*
Carbonic acid gas	at 55° —	108.
Sulphuretted Hydrogen	60° —	108.
Nitrous Oxyd - - -	60° —	77.
Nitrous Gas - - -	ditto —	5.
Oxygen - - - -	ditto —	3·55
Phoſphuretted Hydrogen	ditto —	2.14
Carbonic Oxyd - - -	ditto —	2.01
Carburetted Hydrogen	ditto —	1.40
Azotic Gas - - -	ditto —	1.47
Hydrogen - - - -	ditto —	1.53

The abſorption of atmoſpheric air cannot be well eſtimated as it is partially decompoſed by water, the oxygen being abſorbed in preference to the azot.

* * *

In the chemical examination of gaſſeous bodies, eſpecially in the nicer reſearches of decompoſition, it is of great importance to exclude all extraneous bodies and particularly *moiſture*. All gaſſes probably without exception are capable of holding in ſolution very variable quantities of moiſture, and as this latter is decompoſable into oxygen and hydrogen by the electric ſpark and other methods, much error may be induced from this ſource. The ſtate of moiſture or dryneſs of common air is indicated by the hygrometer, an inſtrument the uſe of which hardly comes under the province of chemiſtry. So eager is the attraction of dry air for moiſture that if a quantity be ſhaken for an inſtant with a few drops of water in a ſmall veſſel, it almoſt immediately becomes ſo far ſaturated with it as ſtrongly to affect the hygrometer.

For chemical purpoſes, gaſſes are rendered of an uniform, at leaſt, if not perfect ſtate of dryneſs, either by paſſing them through a heated tube, or better by expoſing within them ſome ſubſtance which itſelf ſtrongly attracts moiſture. Several of theſe are uſed apparently with equal effect. A ſmall quantity of concentrated ſulphuric acid, a piece of fuſed cauſtic potaſh, or ſome dry powdered muriat of lime, will all anſwer the ſame purpoſe, and render the gas within uniformly dry when ſuffered to remain in contact with them for about an hour.

* * * *

In all experiments on gaſſes, it is neceſſary in order to give comparable reſults, to pay attention to ſome circumſtances that influence their apparent quantity and bulk. Theſe are, the *Expanſion by Heat*, and conſequent contraction by cold, and the change in volume produced by the degree of *Preſſure*, both atmoſpherical, and that which is often occaſioned artificially by the mode of confining the gas by the apparatus employed.

1. *Of the Expanſion by Heat.*

Gaſſeous bodies expand immediately and very largely (comparatively with other natural bodies) by any addition of heat, and hence they form by far the moſt delicate material for thermometers, though their uſe is much leſſened by the counteracting and ſuperadded effect of preſſure.

Many experiments have been made on the expanſion of common air by heat, and the rate of enlargement has been given with conſiderable variation. But the accurate experiments of Dalton in England and Luſſac in France, are found to coincide ſo cloſely and were both conducted with ſuch apparent accuracy that we may ſafely adopt them in our calculations.

Mr. Dalton[b] found repeatedly that 1000 parts of common air at 55° temperature (dried by the contact of ſulphuric acid, and under unvarying atmoſpherical preſſure) expanded to 1321 parts when heated from this point to 212° in a manometer tube, to which 4 parts muſt be added for the correſponding expanſion of the glaſs, and hence 325 parts are the increaſe upon 1000, by 157 degrees of heat, carried up to 212°. This therefore gives 2.07 increaſe upon 1000 parts of air by the addition of a ſingle degree of heat, from 55° to 212°. The expanſion however *appeared* to be not quite equal for equal

[b] Mancheſter Mem. vol. v. pt. 2.

increments of heat, through the whole ſcale; for it was found to be 167 parts for the firſt $77\frac{1}{2}°$ degrees above 55°, and only 158 parts for the next $77\frac{1}{2}°$, and the ſame difference obtained throughout, ſo that the expanſion appeared to be in every part of the ſcale a gradually diminiſhing one in aſcending. This difference however, Mr. D. ſhews to be probably only apparent, and to be owing to the circumſtance firſt explained by M. de Luc, namely, that liquids do not expand quite equally for equal increments of heat, but in a ratio always increaſing, though ſlowly, up to the boiling point of the liquid. Hence it follows that the thermometer does not meaſure quite correctly equal increments of heat, ſo that the expanſion of the thermometrical fluid which correſponds with ten degrees (for example) on the top of the ſcale, really indicates a leſs actual addition of caloric, than the ſame number of degrees lower down in the ſcale, or nearer the freezing point. Therefore the firſt $77\frac{1}{2}°$ degrees above 55° indicate an actual greater quantity of caloric than the ſecond $77\frac{1}{2}°$, which will account for part at leaſt of the difference of actual expanſion between 167 and 158. However, whilſt the thermometer continues to be uſed as a perfect meaſure of equal portions of heat, the ſlight error thus induced muſt be allowed for.

In making experiments on the ſcale of expanſion of any gas, the mode of drying with ſulphuric acid, or any equally good way muſt be particularly obſerved in the colder temperatures, otherwiſe the conſequent precipitation of moiſture ſuſpended in the gas would further embarraſs and miſlead the operator.

The experiments of M. Luſſac [b] coincide in a moſt ſatisfactory way with thoſe of Mr. Dalton, and explain the reaſon of many of the anomalies in the reſults of the obſervations of other philoſophers. By an ingenious apparatus M. Luſſac found that 100 parts of common dry air at the freezing point, expanded by the heat of boiling water to 137.5 (taking the mean of ſix ſucceſſive experiments, in which the greateſt reſult was 137.61, and the loweſt 137.40). This therefore would give an increaſe of 37.5 upon 100 for 180 degrees, or 0.209, nearly, upon 100 for every ſingle degree of heat from 32° to 212°, ſuppoſing the thermometrical ſcale meaſured exactly equal increments of heat throughout.

Mr. Dalton's experiments gave an increaſe of 32.5 parts upon 100 for the 157 degrees between 55° and 212° which (extended to 180 degrees by ſimple proportion) would give an increaſe of 37.26 parts for 180° or .207 upon 100 for every ſingle degree. But on account of the ſlowly increaſing ratio of expanſion of all fluids in proceeding towards the top of the ſcale of heat, it muſt follow that in bringing Mr. Dalton's experiments to a compariſon with the other by extending the proportion from 55° down to 32°, it is thereby rated ſomewhat too low, which brings the two reſults ſtill nearer. We may therefore take the following as an average (ſetting out of the queſtion the ſmall inequality of expanſion, which is very ſeldom of any practical importance) namely, that 100 parts of common air gain .208 of bulk, or about $\frac{1}{480}$ by the addition of every degree of heat in all the ordinary temperatures at which experiments are made.

Both the above experimenters alſo found that the expanſion of the other gaſſes was *the ſame as that of common air*, the ſlight differences being fairly attributed to the difficulty of conducting ſuch nice experiments with perfect uniformity. Mr. Dalton found this reſult with hydrogen, carbonic acid, oxygen and nitrous gaſſes. M. Luſſac with the above and with azot. With regard to the quantity of moiſture in air, it appears that this only affects the uniformity of expanſion when the temperature is ſo low that a part of it is precipitated, for when in compleat ſolution in the air, it acts only like any other gas with regard to the circumſtance of expanſion.

In giving the volume of gaſſes they are generally underſtood in this country to be at the temperature of 60°, and therefore, from what has been above-mentioned, when above or below this point the neceſſary corrections ſhould be made, allowing an increaſe of bulk, or *vice verſa*, of .208 upon 100 parts for every degree of temperature in which it exceeds or falls ſhort of this point. Thus a gas which occupies 30 cubic inches at 50° muſt be reckoned as equal to 30.624 at 60°, for 100 inches increaſe to 102.08 by 10 degrees of heat, and 100 : 102.08 : : 30 : 30.624. Therefore alſo in operating in ſmall quantities, ſuch as a few cubic inches only, it will often happen that no very great practical error can ariſe from ſlight differences in temperature, ſince 2 cubic inches (or above an ounce in meaſure) of gas, will not expand by the addition of 2 degrees of heat quite $\frac{1}{100}$ of an inch, which is generally the leaſt quantity indicated by any graduated veſſel that chemiſts employ.

[b] An. Chem. tom. 43, p. 137.

2. *Of Preſſure.*

The next circumſtance to be conſidered as affecting the volume of gaſſes is the preſſure to which they are expoſed, for, being elaſtic bodies, their bulk of courſe muſt be leſſened by increaſed preſſure, and *vice verſa*. Gaſſes are almoſt always in different experiments expoſed entirely or partially to the atmoſpheric preſſure, modified by the artificial preſſure ariſing from the height of the column of liquid by which they are confined.

The allowance to be made for preſſure is perfectly ſimple, as it has been fully aſcertained that the diminution of the bulk of a gas is in direct proportion to the compreſſing force. Thus if four cubic inches of air taken when the barometer is at 28 inches, is confined in a bent ſyphon tube cloſed at one end, and a column of 28 inches in height of mercury is poured in, the confined air will be diminiſhed one half in bulk, and will be only 2 cubic inches, as it is now expoſed to double the atmoſpherical preſſure. Thus in every inſtance the bulk of the air is inverſely as the preſſure, and therefore, for example, a quantity of gas which occupies 100 cubic inches when the barometer is at 29.4 inches will be reduced to 98 inches, when the barometer is 30 inches, for 100 is to 98, inverſely as 29.4 to 30, or directly as 30 : 29.4. No uniform ſtandard of barometer is adopted in the regiſter of chemical experiments as that of 60° is of the thermometer. In general however either 30 or 29.5 inches of the former are choſen, the average preſſure being uſually between theſe two numbers.

An artificial diminution of barometrical preſſure is produced when a quantity of air is confined over a column of liquid, particularly mercury, the level of which within the jar is higher than the level of the mercury without. In this caſe the confined air occupies a larger ſpace than it would, were the mercury within and without upon a level; becauſe the weight of the air is not counterbalanced entirely by the elaſticity of the air within the jar, but is partly counterbalanced by the weight of ſo much of the mercury within as is above the level of that without.

This circumſtance if not attended to (which there is reaſon to ſuppoſe too often happens) is particularly liable to give a falſe idea of the nature of the gas in analyſis as generally conducted. For ſuppoſing when the barometer is at 30. a quantity of gas is expelled from any mineral water (for example) by heat, and is received in an inverted jar full of mercury, and ſtanding over the ſame fluid, if the jar is 11 inches high, and only the 6 upper inches of mercury are diſplaced by the gas, the latter will then be ſuperincumbent on a column of mercury 5 inches above the level of the fluid on the outſide. It will then appear as if 6 inches of gas at 30 bar. have been procured, but this will exceed the true amount exactly in the proportion that 30 exceeds 30—5, or 25, the effect of the inner column of 5 inches of mercury being to counterpoiſe, and therefore to annihilate, an equal quantity of the atmoſpherical preſſure, ſo that this will act on the incloſed gas with a force of 25 inches inſtead of 30; therefore the true amount of the gas will be only 5 inches inſtead of 6; for, 30 : 30—5 (25) : : 6 : 5. If now, in the uſual courſe of analyſis, ſome lime water is let up into the jar, the column of 5 inches of mercury will be diſplaced by the aſcending lime-water, and the counteracting power to the atmoſpherical preſſure will be now only that of 5 inches of watery fluid, inſtead of mercury, that is to ſay, it will be reduced to about one-fourteenth of its former power, (mercury being 14 times heavier than water) and hence the gas within will now contract to nearly its natural dimenſions, and meaſure only about 5 inches. Thus therefore an apparent abſorption of nearly one inch of the gas by the lime-water will be produced without a particle of air being really abſorbed; and if at the ſame time a portion of carbonic acid is preſent (ſuppoſe one inch) the lime-water will become turbid and abſorb this latter, and the reſult of the experiment will be 6 inches of gas, containing 2 of carbonic acid; inſtead of 5 inches, containing 1 of carbonic acid.

This ſource of error may be obviated in two ways, that is, either by ſinking the jar ſo deep into the mercury that the fluid within ſhall be on the ſame level with that without, and the other by making the neceſſary allowance for the diminiſhed preſſure on the ſame principle that changes of common barometrical preſſure are eſtimated. The former way is the beſt where it is practicable, being ſurer and not requiring the trouble of calculation. Where the mercurial bath has not a well deep enough to ſink a tall jar into it, and where the gas cannot be conveniently transferred into a ſhorter jar, it will not be difficult to remove the jar holding the gas and mercury, into another jar full of the ſame fluid, and juſt large enough to admit the former to be ſunk into it to the requiſite depth. In operating with water inſtead of mercury the

preſſure of a column of a few inches as already mentioned, will make ſo ſmall a difference that it may be almoſt always diſregarded.

But where it is impracticable to bring both ſurfaces to the ſame level the requiſite correction muſt be made in the following manner: meaſure with a ruler the perpendicular height of the inner column of mercury above the level below, and find what proportion it bears to the height of the barometer at that time: then, as the whole barometrical height is to the ſame *minus* the height of the inner column; ſo is the number of cubic inches now occupied by the gas, to the true number under the entire atmoſpherical preſſure. For example, if the height of the inner column be 7 inches, the barometer 28 inches, and the volume of the gas 84 cubic inches, then the true volume will be one-fourth leſs, or 63 cubic inches, (the inner preſſure being equal to and counteracting one-fourth of the outer) for 28 : 28—7 (21) : : 84 : 63.

Where this correction is made in jars accurately cylindrical and graduated, when the inner column of mercury is diſplaced by water, the height to which the latter will immediately riſe above the level of the mercury which it has diſplaced, will be ſeen to be exactly in the ſame proportion to the whole height of the part of the jar firſt occupied by the gas, as the diminution of bulk is to the entire bulk of the gas when confined by the mercury.

In all theſe operations therefore it ſhould always be remembered that when any gas is confined by an elevated column of mercury a diminution in bulk on throwing up any other liquid does not neceſſarily imply an abſorption by that liquid till the requiſite allowance has been made for this artificial expanſion of the gas which the column of mercury produces.

We may conclude this article with one example of all the three corrections in eſtimating the volume of gaſſes. What will be the true volume of 75 cubic inches of gas confined in a jar by a column of mercury 6 inches above the level of the mercury without the jar, the barometer being 30 inches and the temperature 35° when brought to the ſtandard of 29.5 bar. and 60° therm.?

Firſt for the correction required by the different levels of the mercury without and within the jar we have the 75 inches reduced to 60, for 30 : 30—6 (24) : : 75 : 60. Then the 60 cubic inches at 30 barometer when brought to the required preſſure of 29.5 will be enlarged to 61.01, for 29.5 : 30 : : 60 : 61.01.

Laſtly, for the 25 degrees of encreaſed temperature, as 100 parts gain .208 by each degree they would gain 5.2 for the 25 degrees, and hence the 60.01 would gain 3.173 for 100 : 5.2 : : 61.01 : 3. 17. Therefore the 61.01 cubic inches at 35° will be encreaſed to 64.18 cubic inches at 60°, ſo that the true volume of the 75 cubic inches under all the circumſtances above mentioned, will be 64.18 at 29.5 barometer and 60° thermometer.

The methods of managing experiments on gaſſeous bodies will be deſcribed in the *Appendix of Apparatus*, and the teſts of the particular gaſſes and the methods of analyſis will be found under the reſpective articles.

GASSEOUS OXYD OF AZOT. See NITROUS OXYD.

GASSEOUS OXYD OF CARBON. See CARBONOUS OXYD.

GAS-HOLDER. An article of chemical apparatus. *(See the Appendix.)*

GASTRIC JUICE.

This is a thin limpid watery fluid ſecreted into the ſtomach of all animals and appears to be the chief agent in the converſion of food into nutritive matter by the proceſs of digeſtion.

The analyſis of this fluid has excited much of the attention of ſeveral phyſiologiſts as being cloſely connected with all attempts to explain the important proceſs of digeſtion, but with no other reſult than to ſhew that mere chemical reaſoning, in the preſent ſtate of knowledge, is entirely inadequate to the purpoſe, the gaſtric fluid ſhewing in analyſis no important or peculiar ſubſtance which can at all throw any light on the cauſe of its remarkable properties.

There are ſeveral methods of collecting this juice in greater or leſs purity. The ſimpleſt is to keep the animal for ſome time faſting, when on killing it a conſiderable quantity of gaſtric juice will be found in the ſtomach, and which probably is the immediate cauſe of the ſenſation of hunger. In this manner Spallanzani collected a quart of the juice from the ſtomach of a ſheep kept faſting for two days before it was killed. Another method is to excite vomiting in an animal kept for ſome time faſting, when the liquor ejected will be chiefly gaſtric juice, but mixed with a little bile and ſaliva.

Another method uſed by Reaumur and Spallanzani is to make the animal ſwallow ſmall dry ſponges looſely encloſed in perforated hollow metallic balls to prevent their being ſqueezed by the muſcular action of the ſtomach. When theſe balls are ejected after being ſome

hours in the ſtomach the ſponges are ſoaked with gaſtric juice of conſiderable purity.

Notwithſtanding the uniformity in the effects of gaſtric juice on animal and vegetable matter the chemical analyſis ſhews a conſiderable variety in the number and proportion of the ingredients, but on the whole theſe are in very ſmall proportion to the mere watery part. Much of this variety may depend on caſual admixture with the other animal juices, and the ſmall portion of food ſtill remaining in the ſtomach, which probably no endurable length of faſting will entirely remove, and much certainly depends on the general food of the animal, that is, whether habitually carnivorous or herbivorous, or made ſo contrary to nature by artificial habit. The only conſtant ingredients of gaſtric juice appear to be muriatic acid, ſoda, ammonia, and phoſphoric acid in their different combinations, and a ſmall but never abſent portion of animal extractive matter, the whole diſſolved in a very large portion of water. It very frequently happens that this liquor ſhews marks of acidity, but this property is not conſtant, and there is conſiderable reaſon to ſuppoſe that this may ariſe from caſual admixture with ſome acid ariſing from the food itſelf.

This liquid is remarkable for two properties which it poſſeſſes to an extreme degree, and which ſeem neceſſary to the function of digeſtion, but nevertheleſs cannot be accounted for on any of the known qualities of its ingredients: theſe are its powers of *coagulating* all coagulable liquids, and its *antiſeptic* power, or that of preventing the putrid fermentation of animal matter, or correcting it when formed.

Experiments on this ſubject belong more to phyſiology than pure chemiſtry, but it may be obſerved that the power of coagulation of ſubſtances in contact with gaſtric juice alſo ſeems to reſide in the ſtomach itſelf, and is familiarly known by the uſe of the common *rennet* for ſeparating the curd from milk in cheeſe-making, which is an infuſion of the digeſting ſtomach of the calf in ſalted water. The antiſeptic power of the gaſtric juice is ſtrikingly ſhewn in thoſe animals (the vulture and the weaſel for example) who readily devour their food in the moſt diſguſting ſtate of putrefaction, and in whom it is found to loſe moſt of its putreſcency after remaining a ſhort time in their ſtomach. The gaſtric juice has alſo a ſimilar power out of the body.

The actual analyſis of the gaſtric juice of the ſheep is thus given by Macquart. [a]

Twenty ounces yielded 77 grains of ſolid matter, the reſt being mere water.—Theſe 77 grains conſiſted of

	grs.
Phoſphoric acid	17
Phoſphat of lime	5
Muriat of ammonia	14
Muriat of ſoda	29
Albumen	10
Reſinous and extractive matter	2
	77

Other analyſes ſhew a conſiderable variation in the ingredients, which are of themſelves utterly incapable of explaining the effects of the liquor, all of them find the common ſalt to be in the largeſt quantity, and phoſphoric acid either naked or in combination to be conſtantly preſent.

GAZOMETER. An article of Chemical Apparatus. *(See the Appendix.)*

GELATIN, or ANIMAL JELLY. *Gallerte Thieriſche*, Germ.

This is a moſt abundant principle in a vaſt variety of the parts of animals, and appears to be one of the great elementary conſtituents of animal organization. Scarcely any organ is without it, but it is moſt abundantly contained in ſkin, in moſt of the ſoft and white parts, in bone, and the hard bony horns, in membrane of all kinds, in the blood in ſmall quantity, and alſo in ſmall proportion as the natural cement of many of the ſhells.

From all of theſe ſubſtances gelatin is extracted ſimply by boiling in water for a greater or leſs time, according to the hardneſs or toughneſs of the ſubſtance employed. This watery ſolution is tranſparent and colourleſs, or nearly ſo, and when gently evaporated to a ſmall bulk and ſuffered to cool it *gelatinizes*, or aſſumes the conſiſtence of cohering, extremely flexible and mobile, ſoft, tremulous *jelly*, ſuch as is known to every one as prepared for the table.

By further evaporation, the watery ſolution of gelatin may be rendered hard and brittle, in a degree partly determined by the degree of evaporation, and partly by the original gelatinizing force of the ſubſtance that yields it. In this ſtate it forms the ſolid carpenter's *glue*, or of leſs ſtiffneſs the different kinds of *ſize* uſed as cements in ſo many of the arts. The preparation of theſe will be deſcribed after mentioning the chemical properties common to pure gelatin of every deſcription.

[a] Phyſ. tom. 2. Johnſon's Animal Chem.

Chemiſtry is indebted to Mr. Hatchett for a moſt valuable ſeries of experiments on gelatin, and ſubſtances yielding it, in which many important and characteriſtic chemical diſtinctions are pointed out. [a]

In all caſes this ſubſtance when pure is abſolutely inſipid, tranſparent, and nearly colourleſs, or only with a ſhade of yellow. It is alſo without ſmell. Dry gelatin when thrown into water gradually abſorbs it, ſwells to many times its original bulk, ſoftens, and becomes extremely elaſtic. It does not however diſſolve therein as long as it remains cold, but if taken out and put in a very warm dry air, it again ſhrinks, and returns nearly to its former conſiſtence. But if heat is applied to gelatin thus ſwelled by ſoaking and immerſed in more water, it very ſpeedily diſſolves, forming a ſolution exactly reſembling in chemical qualities the original liquor from which the dry gelatin was prepared, of the ſame denſity, and therefore again gelatinous by cooling. It is therefore an inherent and alſo a very characteriſtic property of gelatin to be ſoluble in water and recoverable from the ſolution by evaporation unaltered, for an indefinite number of times, even after long application of a boiling heat. In this it eſſentially differs from the ſolution of albumen, which coagulates by heat and does not again return to its ſoluble ſtate.

All kinds of gelatin are ſoluble in all the acids, and with the ſame comparative readineſs with which they yield to the action of water. The nitric acid acts with particular energy on gelatin, even when conſiderably dilute and in the cold, and this is a very convenient method of ſeparating it from the condenſed albumen which often exiſts in natural combination with it. Thus if cartilage is immerſed in weak nitric acid and allowed to remain in for a day or two, all the gelatin and any earthy matter which it may contain gradually diſſolves, leaving a firmer ſubſtance retaining the original ſhape of the cartilage, which the acid when dilute will not touch. The nitric ſolution of gelatin (of iſinglaſs for example) is of a pale yellow deepening by evaporation. When much concentrated the acid which at firſt appears to act merely as a ſolvent, is decompoſed by the gelatin, and nitrous gas is given out, ſometimes attended with ſparks or flame. This mutual decompoſition of nitric acid and gelatin produces alſo a quantity of the oxalic and malic acids, which are to be detected in the liquor if the concentration has not proceeded ſo far as again to decompoſe theſe new products.

The acid ſolutions of gelatin give no precipitate when ſaturated with any of the alkalies or earths.

The muriatic acid diſſolves gelatin in the cold with great eaſe, and like the nitric ſeparates it from the denſe albumen of organized bodies with which it is naturally combined. The muriatic ſolution may be kept unchanged for many months.

The cauſtic fixed alkalies diſſolve gelatin with great eaſe, forming a browniſh viſcid ſubſtance, but no ammonia is given out during the ſolution. This viſcid alkaline ſolution, according to Mr. Hatchett, does not poſſeſs the properties of ſoap, for it does not form a permanent lather when ſhaken with water, nor when ſaturated with acid does it afford any precipitate. This Mr. H. gives as a very characteriſtic property, diſtinguiſhing pure gelatin from albumen, fibrin, and moſt other ſoft parts of animals, all of which latter form a true ſoap with alkalies, that curdles and precipitates on ſaturation with an acid.

Gelatin is inſoluble in pure alcohol, and when this ſpirit is poured into a watery ſolution of gelatin, the mixture becomes milky and part of its gelatin ſeparates (as takes place with the vegetable mucilages and alcohol) but unleſs a very large quantity of ſpirit is added the mixture again becomes clear.

Gelatin when hard and dry will keep for a great length of time without change, but when liquid or in the thin gelatinous ſtate, it very ſoon putrefies, firſt growing ſour by the generation of acetic acid, then mouldy and fetid, and at laſt exhaling ammonia.

When dry gelatin is ſtrongly heated, it curls up and becomes puffy, and yields an oily ammoniacal liquor, like all other ſoft parts of animals. In cloſe veſſels it leaves at laſt a bulky ſoft coal, the proportion of which according to Mr. Hatchett, is 56 grains from 500 of iſinglaſs. This by incineration in open air burns away entirely, except 1.5 gr. of earthy reſidue, which appears to be the phoſphats of ſoda and lime. The quantity of earthy and ſaline matter therefore is extremely ſmall compared with that of the other ſoft parts.

The ſame chemiſt has alſo obſerved a kind of artificial converſion of condenſed albumen into gelatin by long digeſtion in dilute nitric acid, the albumen thereby becoming perfectly ſoluble in water, and forming a gelatinizing ſolution when reduced by evaporation.

The extent of the *gelatinizing power* of the pure gellies, or the power of uniting with ſo

[a] Phil. Tranſ. vol. 90.

much water as ſtill to remain a ſtiff cohering maſs when cold, is ſhewn by the experiments of Dr. Boſtock,[b] who found that when water contained no more than $\frac{1}{100}$ of its weight of iſinglaſs it ſtill compleatly ſtiffened by cooling, and even when only $\frac{1}{150}$, the ſolution was evidently gelatinous when cold, though not abſolutely concrete.

The moſt ſingular combination of gelatin and that which is moſt uſeful as a chemical teſt is with tan. If a ſolution of gelatin, of glue or iſinglaſs for example, is added to an infuſion of oak bark, galls, catechu, or any other vegetable that contains the tanning principle a copious white precipitate ſeparates, which when the reſpective liquors are concentrated may be collected by the fingers with great eaſe, and forms a ſingular grey ductile maſs, ſmelling like tanned leather, and which dries into a dark brown brittle maſs of the appearance of reſin, inſoluble in water, and incapable of putrefaction. This combination, which appears to be chemically the ſame as highly tanned leather, will be further noticed under the article TAN.

The power of infuſion of tan as a teſt of gelatin is very extenſive. Dr. Boſtock found a copious and immediate precipitate on adding a moderately ſtrong infuſion of galls to water holding only $\frac{1}{1000}$ of iſinglaſs, and a very conſiderable precipitate when the gelatin was only $\frac{1}{5000}$.

The ſolutions of albumen alſo give a precipitate with tan, but not till after ſtanding together ſome hours, and therefore when uſed as a teſt, an immediate precipitate with tan, may be conſidered as a pretty certain indication of gelatin.

The nitro-muriat of tin alſo produces a white precipitate with gelatin, but unleſs the ſolution of the latter is pretty ſtrong, the effect is only a white cloud, after ſome hours ſtanding. Nearly the ſame effect is produced with the ſolutions of albumen.

The difference in the degree of viſcidity and tenacity of the varieties of gelatin, is as Mr. Hatchett obſerves, an inherent quality, and not cauſed by the degree of mere inſpiſſation, otherwiſe when each variety was perfectly dry, they would each make a glue or cement of exactly the ſame degree of tenacity, which is known not to be the caſe. On the contrary the tenacity depends partly on the age of the animal, the old giving a much ſtronger glue, *ceteris paribus*, than the young: and partly on the ſubſtances that furniſh it, the glue from the ſkin being much ſtronger than the ſolid gelatin from the bones, ſinews, or any other part. In proportion as the glue is more adheſive, it becomes leſs eaſily ſoluble in water, and abſorbs a larger portion before it comes to the ſtate of tremulous gelly. Mr. Hatchett alſo found that the force of adheſion of the glue from ſkin was generally proportionate to the toughneſs of the ſkin, the ſoft flexible ſkins yielding a thinner gelatin than the hard bony ſkins, and with much more eaſe.

GLUE, ſuch as is made by the carpenters, appears to be made in greater perfection in this than in any other country, if we may judge of the eſtimation in which Engliſh glue is held abroad. The minute circumſtances of the operation which give a ſuperiority of the article of one manufacturer over another cannot be readily aſcertained, but the following is given by Mr. Clennel as the general mode of manufacture.[c] "Glue is an inſpiſſated gelly, made "of the parings of hides or horns of any kind, "the pelts obtained from furriers, the hoofs "and ears of horſes, oxen, calves, ſheep, &c. "Theſe are firſt digeſted in lime-water, to "cleanſe them from greaſe or dirt, they are "then ſteeped in clean water with frequent "ſtirring, afterwards laid in a heap and the "water preſſed out. They are then boiled in "a large braſs cauldron with clean water ſkim-"ming off the dirt as it riſes, and it is further "cleanſed by putting in, after the whole is diſ-"ſolved, a little melted alum or lime finely "powdered. The ſkimming is continued for "ſome time, after which the maſs is ſtrained "through baſkets, and ſuffered to ſettle that "the remaining impurities may ſubſide. It is "then poured gently into the kettle again, and "further evaporated by boiling and ſkimming "till it becomes of a clear darkiſh brown "colour. When it is thought to be ſtrong "enough it is poured into frames or moulds "about ſix feet long, one broad, and two deep, "where it gradually hardens as it cools, and "is cut out when cold by a ſpade into ſquare "cakes. Each of theſe is placed in a ſort of "wooden box open in three diviſions to the "back, in this the glue while yet ſoft is cut "into three ſlices by an inſtrument like a bow, "with a braſs wire for its ſtring. The ſlices "are then taken out into the open air, and "dried on a kind of coarſe net-work, faſtened "in moveable ſheds four feet ſquare, which are "placed in rows in the glue-maker's field. "When perfectly dry and hard it is fit for "ſale. That is thought to be the beſt glue

[b] Edinbg. Med. and Phyſ. Journ. No. 2.

[c] Monthly Mag. for 1802, p. 5.

" which ſwells conſiderably without melting by " three or four days immerſion in cold water, " and recovers its former dimenſions and pro- " perties by drying. Glue that has got froſt " or that looks thick and black, ſhould be " melted over again. To know good from bad " glue the purchaſer ſhould hold it between his " eye and the light, and if it appears of a " ſtrong dark colour, and free from cloudy or " black ſpots, the article is good."

To this diſtinct and apparently accurate account of glue-making, may be added ſome experiments by Pelletier,* on a glue from bones, made in France by a M. Grenier, from the raſpings and trimmings of ivory, the refuſe pieces and ſhavings of the button-mould makers, and other kinds of hard bone, that cannot be turned to account in entire manufacture. Six pounds of button-mould ſhavings were put into a copper boiler with 24 quarts of water, and firſt let to ſoak for two hours in the cold. The fire was then kindled and the liquor ſlowly brought to boiling, and kept at this heat for nine hours. After ſtanding a night 14 quarts of clear gelatinous liquor were drawn off by a ſyphon, and two quarts more were obtained by preſſing the reſidue. This was duly evaporated without addition, and when of the proper conſiſtence was allowed to ſubſide for half an hour, when it became firm enough to be cut into cakes, which being then hung up for a fortnight in a barn yielded about 15 ounces of ſolid glue, or rather leſs than a ſixth of the weight of the bone ſhavings originally uſed. A ſimilar experiment made with ivory-turnings yielded nearly the ſame proportion of glue. The gelly from theſe clean white bones is at firſt very tranſparent and with little colour, but when concentrated by evaporation it always deepens in colour, but if well made ſtill remains tranſparent. A piece of this glue put into cold water ſwelled, as happens with common good glue, and in 24 hours had abſorbed 15 times its weight of water, but without diſſolving, and by again drying in the air, it returned to its original bulk and weight. It appears that at Paris there are three ſorts of glue commonly ſold, the beſt is that which is imported from this country, and is of a deep red, the next in value is the Flemiſh, which is whitiſh and tranſparent, and the moſt ordinary glue of the country is black and opake.

In uſing glue, the carpenters firſt break it and cover it with cold water, and let it ſtand for about twenty-four hours, by which, as already mentioned, it ſwells to many times its original bulk, and abſorbs a large quantity of this fluid, after which the ſoaked pieces are melted, without more water, over a ſlow fire, and kept ſimmering for about a quarter of an hour with frequent ſtirring and are then cooled. It is now a firm gelly, of ſuch a conſiſtence, as very readily to be cut by any inſtrument, but too ſtiff to be tremulous. When wanted to be uſed, it is merely warmed which renders it ſufficiently fluid to be ſpread over the ſurface of the wood with a ſtiff bruſh. Wood joined by glue requires from one to three days to be perfectly cemented, which is known by the hardneſs of the portion that remains on the outſide of the joining, and the force of coheſion of the beſt glue is ſuch, that boards as thick as any commonly uſed in furniture carpentry will full as readily give way by violence in any other part of the ſubſtance as at the joining. Glued boards will not ſet in a freezing temperature, the ſtiffening being owing to the evaporation of the ſuperfluous water of the glue which is prevented by great cold.

* * *

A variety of gelatinous cements of leſs firmneſs than common glue, and known by the general term of *Size*, are made for the uſe of the paper-hangers, gilders, bookbinders, houſe-painters in diſtemper, and many other trades, by boiling down in water the clippings of parchment, glove-leather, fiſh-ſkin, and many other kinds of ſkin and animal membrane. Theſe are uſed either alone or mixed with vegetable tenacious ſubſtances, ſuch as flour-paſte, gum-arabic and tragacanth, and the like. The preparation of theſe jellies is perfectly ſimple, the ſubſtance uſed (parchment ſhreds for example) being ſimply diſſolved in water by boiling, ſtrained and evaporated to a due conſiſtence. Eel-ſkins and the ſkins of other fiſhes make a cement which is much valued for its tranſparency and tenacity. The only ſpecies of gelatin of this kind uſed in the arts which requires further notice is

Isinglass.

This is a thin, flexible, tough, whitiſh membrane, in the form of irregular ſhreds or clippings looſely coiled up, and of different degrees of fineneſs and flexibility, which is procured from ſeveral parts of the entrails of ſeveral fiſhes, with ſcarcely any artificial preparation than that of extracting, cleanſing, and drying.

The fineſt kind of iſinglaſs is that which has the longeſt *ſtaple* as it is called, and which is

* Mem. de Pelletier, tom. 2.

the thinneſt and moſt flexible. The preparation of iſinglaſs is almoſt peculiar to Ruſſia,[d] and is made in all places on the vaſt rivers of this mighty empire, where the large ſturgeon and other fiſhes of this genus are caught, as on the Dnieper, the Don towards the Caſpian Sea, the Volga, Oby, Irtiſh, and other Aſiatico-Ruſſian rivers. The beſt iſinglaſs is that which is prepared from the ſturgeon. The membranes which, when dried, form iſinglaſs, are various extenſions and proceſſes of the peritoneum, but more particularly the air-bladder, or ſounds, which is very large in theſe fiſhes. The ſounds when taken out of the fiſh are firſt waſhed with cold water, and expoſed a little to ſtiffen in the air. The outer ſkin is then peeled off and thrown away. The remainder is ſimply cut out and looſely twiſted into rolls according to the intended ſize of the ſtaple, which are pegged down on boards, and hung up on lines to dry. No other preparation is uſed. An inferior kind of cake-iſinglaſs is made by taking all the clean ſhreds of the twiſted ſort, putting them in a flat metal-pan with a very little water, and heating juſt enough to make a cohering maſs. This is afterwards dried. It would be tedious to enumerate the minute varieties of iſinglaſs or fiſh gelatin.

Good iſinglaſs is eſteemed the fineſt and pureſt ſpecimen of animal gelatin. It is entirely without taſte or ſmell, when ſoaked in water it ſwells, ſoftens, and if held up to the light is agreeably opaleſcent to the eye. It readily and totally diſſolves in warm water, forming the cleareſt and moſt colourleſs of all the known jellies. The finer ſorts are much too valuable to be uſed for the ordinary purpoſes of a ſize or cement, but are principally employed in confectionary, in clarifying wines, and other purpoſes of the table.

When the jelly of iſinglaſs is much concentrated by evaporation, it forms a delicate cement for joining glaſs, &c. for which its great tranſparency and freedom from colour render it highly valuable. The coarſer ſort of fiſh-glue cake, or that which conſiſts of refuſe bits of iſinglaſs, brought to a cohering maſs by water, is often uſed for the ſame purpoſes as common glue. This when foul and blackened is bleached by expoſure to the vapour of ſulphur,[e] which, on account of the looſe fibrous texture is able to penetrate it ſufficiently, an effect which could not take place with the ſolid cakes of common glue.

ANIMAL MUCILAGE.

In ſome parts of the body of man and different animals is found a ſomewhat clammy, inſipid, whitiſh or often colourleſs liquor, uncoagulable by heat, but leaving after a gentle evaporation to dryneſs a ſmall proportion of ſlimy tenacious matter, much reſembling gelatin in appearance, and in being equally again ſoluble in water. The ſaliva is perhaps the beſt example of ſimple animal mucilage in the human body, but it is found more copiouſly in other animals, as for example, in the oyſter, and many marine inhabitants.

Animal mucus or mucilage differs however from gelatin in being readily ſoluble in cold water, and eſpecially in having no proper gelatinizing power, that is to ſay, a hot ſolution does not ſtiffen, or approach apparently more to the ſolid ſtate by cooling, but its degree of viſcidity depends ſimply on the proportion of water in the ſolution without regard to temperature.

Mr. Hatchett conſiders mucus, however, as a ſpecies of gelatin the loweſt in the coheſive power, or at one extremity of the ſcale of tenacity, at the other extremity of which is the ſtiffeſt glue from condenſed ſkin.

But Dr. Boſtock has given the following diſtinctive marks which certainly eſtabliſh as clear a difference between mucus and gelatin as exiſts between many other ſubſtances ſtrongly reſembling each other, but which have been allowed a ſeparate place. The mucus of an oyſter was detached by agitation in cold water for a few minutes, when the fluid was filtered and appeared ſlightly opake and gelatinous. By evaporation it appeared that it had diſſolved about $\frac{1}{50}$ of its weight of animal matter. A quantity of this diluted with as much water was tried with the following reagents: a ſolution of corroſive mercurial muriat produced no effect; the infuſion of tan (from galls) after ſome time produced a ſlight turbidneſs, and at length a ſmall quantity of a precipitate. The aqua lithargyri acetati (or vinegar ſaturated with litharge at a boiling heat) gave an immediate opacity, and, after ſome time, a denſe white precipitate.

The firſt of theſe teſts, the mercurial ſolution, is found to precipitate albumen only, and as no effect was here produced, it ſhews the abſence of this principle. The ſolution of tan occaſioned only a very ſlight opacity, but by previous experiments it was found that a ſolu-

[d] Tooke's Ruſſian Empire. Alſo Jackſon in Phil. Tranſ. vol. lxiii. [e] Pelletier.

tion of true gelatin in $\frac{1}{100}$ times its weight of water, or equally dilute with the preſent ſolution, would have given an immediate and copious precipitate with tan, a character ſufficiently diſcriminative. On the other hand gelatin will not be precipitated by acetited litharge, whereas mucus is abundantly affected by this teſt. Theſe differences, therefore, together with the abſence of the gelatinizing property, will, for the preſent, entitle us to conſider mucus as a diſtinct animal principle.

GELBERDE. See YELLOW EARTH.

GEMS. Gems or precious ſtones form a claſs of earthy minerals very diſtinguiſhable in commerce by their ſuperior price, but of which it is not eaſy to give a ſcientific definition. That furniſhed by Boetius de Boot[a] is, perhaps, upon the whole, the beſt which is to be found. "Lapis" ſays he, "alius a Natura magnus, "alius parvus producitur; parvus alius rarus "inventu, alius frequens. Rarus alius durus, "alius mollis. Durus alius pulcher aſpectuque "gratus, alius turpis. Pulcher *Gemmæ* nomen "meretur. Erit itaque gemma lapis parvus, "rarus, durus, et pulcher, a Naturâ procreatus." *Nature forms ſome ſtones large and others ſmall; of the ſmall, ſome are of rare occurrence, others are common; of the rare, ſome are hard, others are ſoft; of the hard, ſome are beautiful and pleaſant to the ſight, others are mean. The beautiful merit the name of Gems. The word gem therefore ſignifies a natural ſtone of ſmall ſize, rare, hard, and beautiful.*

The ancients ſeem to have made a difference between precious ſtones and gems, comprehending under the former term thoſe hard and beautiful, but for the moſt part uncryſtallized ſtones, ſuch as agate, carnelian, onyx, chalcedony, &c. upon which they were accuſtomed to engrave, reſtricting the word gem to thoſe ſtones which, on account of their minuteneſs, extreme hardneſs, and brilliant luſtre, were worn in rings and other ornaments, either in the ſtate in which nature preſents them, or, at moſt, after being cut and poliſhed. Some ſtones, however, ſuch as the topaz and amethyſt, being commoner and in larger pieces than moſt of the other gems, held a kind of middle rank between theſe and the precious ſtones, being ſometimes employed as materials to engrave upon, and ſometimes uſed plain for necklaces, rings, &c.

Bergman in his excellent eſſay on the earth of gems has ſhown, contrary to the general opinion of his day, that the hardneſs and cryſtalline texture of the gems is not owing to their conſiſting almoſt entirely of vitrifiable earth or ſilex; ſince many of the gems, eſpecially thoſe called oriental, appear from analyſis to contain a much larger quantity of alumine than of ſilex. On the other hand, however, this able chemiſt himſelf is deceived when he labours to ſhew that all the moſt perfect gems, including the diamond, are indebted for their hardneſs, exceeding ſpecific gravity and luſtre to the preſence of alumine in their compoſition; it being now fully aſcertained that the diamond when pure is wholly combuſtible, and therefore contains no earth whatever.

The particular gems are deſcribed at large in their proper places; we ſhall therefore only give a liſt of them here, arranging them in four claſſes, according to the relative eſtimation in which when perfect they are held by jewellers; premiſing, however, that this order is ſubject to ſome variations from the caſual plenty or ſcarcity of any particular kind, and from the caprice of faſhion.

The diamond and the oriental ruby conſtitute the firſt claſs. Of theſe, a very ſmall diamond is more valuable than a ruby of equal weight; but rubies of ten carats or more being much rarer than diamonds of equal weight bear a ſomewhat higher price in the market. The ſecond claſs of gems contains the emerald, ſtarſtone, oriental giraſol, ſapphire, ſpinel and balais rubies, oriental topaz, oriental amethyſt, and noble opal. In the third rank are found the jargoon, cat's-eye, oriental chryſolite, hyacinth, and peridot. Thoſe in the fourth and loweſt claſs are often engraved upon, and form the moſt valuable ſeal-ſtones; they are the beryll or aqua-marine, Brazilian topaz, Saxon topaz, Sirian garnet, Bohemian garnet, and European amethyſt.

GEMS ARTIFICIAL. See GLASS *(coloured.)*

GILDING, art of. *L'Art de Dorer*, Fr. *Die Kunſt zu Vergolden*, Germ.

The art of gilding or of laying a thin ſuperficial coating of gold on wood, metal and other ſubſtances has been long practiſed, and highly eſteemed both for its utility and the ſplendid effect which it produces. Gold, from the extreme beauty of its colour, and from the length of time during which it may be expoſed to the action of the air without tarniſhing, is perhaps the moſt valuable of all ſubſtances for the purpoſe of decoration; but on account of its dearneſs and weight it can very ſeldom be employed in ſubſtance, and its ornamental uſe would be limited indeed if it was not at the ſame time

[a] De Gemmis, p. 13.

the moſt extenſible of all ſubſtances: ſo that a given weight of gold, notwithſtanding its high ſpecific gravity, may by beating be made to cover a larger ſurface than an equal quantity of any other body. Among the ancients, the Romans, and among the moderns, the French have been remarkable for their large and profuſe conſumption of gold: not only the temples, theatres, and other public buildings being adorned with gilding, but even the private houſes of the wealthier claſſes.

The materials of gilding, or rather the different ſtates in which gold is uſed for this purpoſe, are the following: leaf-gold, of different thickneſſes and formed either of the pure metal, or of an alloy of this with ſilver, amalgam of gold, and gold powder. The leaf-gold is procured by the gilder from the gold-beater, for an account of which we ſhall refer the reader to the article GOLD; but the other two ſubſtances being prepared by the gilder himſelf may be with propriety deſcribed here. The amalgam of gold is made by heating in a clean crucible ſome pure quickſilver, and when it is nearly boiling adding to it about a ſixth of its weight of fine gold in thin plates heated red hot; the mixture after being kept hot for a few minutes becomes of a perfectly homogeneous conſiſtence, and may then be allowed to cool: when cold it is to be put in a piece of ſoft leather, and by gradual preſſure the fluid part of the amalgam conſiſting almoſt wholly of mercury may be forced through the pores of the leather, while the gold combined with about twice its weight of mercury will remain behind forming a yellowiſh ſilvery maſs of the conſiſtence of ſoft butter. This after being bruiſed in a mortar, or ſhaken in a ſtrong vial with repeated portions of ſalt and water till the water ceaſes to be fouled by it, is fit for uſe, and may be kept for any length of time without injury in a corked vial. It is of eſſential importance that the materials of this amalgam, and eſpecially the mercury, ſhould be perfectly pure, as the leaſt portion of lead or biſmuth would very materially injure the beauty of the gilding by deteriorating the colour of the gold and filling it with black ſpecks; on this account no mercury ought to be employed that has not been procured from diſtillation of the red precipitate (nitrous red oxyd of mercury) either alone or mixed with a little charcoal powder.

Gold powder is prepared in three different ways. The firſt and ſimpleſt is to put into a glaſs or earthen mortar ſome gold-leaf with a little honey or thick gum-water, and grind the mixture for a conſiderable time, till the gold is reduced to extremely minute fragments; when this is done a little warm water will waſh out the honey or gum, leaving the gold behind in a flaky pulverulent ſtate. A leſs tedious and more effectual way of comminuting the gold is to diſſolve it in nitro-muriatic acid and then precipitate it by a piece of copper: the precipitate after being digeſted in diſtilled vinegar and then well waſhed in water and dried, is in the form of a very fine powder, and both works better and is eaſier to burniſh than the ground leaf-gold. The fineſt ground gold however is produced by heating very gradually the gold-amalgam in an open earthen veſſel, and continuing the fire till the whole of the mercury is evaporated, taking care that the amalgam ſhall be conſtantly ſtirred with a glaſs rod or tobacco-pipe, in order to prevent the particles of gold from adhering as the mercury flies off. When the mercury is compleatly evaporated the reſidual gold being then ground in a Wedgewood ware mortar with a little water, and afterwards dried, is fit for uſe.

Gilding is performed either with or without the application of heat. By the firſt of theſe methods thoſe ſubſtances are gilt which are not liable to alteration by expoſure to a moderate heat, ſuch as metals and ſometimes glaſs and porcelain: the ſecond method is practiſed with thoſe ſubſtances, ſuch as wood, paper, leather, ſilk, lacquered and japanned ware, &c. which would be injured, and even deſtroyed at the temperature requiſite for gilding the former. The laſt of theſe methods being the ſimpleſt ſhall be firſt deſcribed; and we ſhall begin with the art of gilding on wood.

There are two methods of gilding on wood, namely, oil-gilding and burniſhed gilding. Oil-gilding is thus performed. The wood muſt firſt be covered or primed with two or three coatings of boiled linſeed-oil and white-lead, in order to fill up the pores and conceal the irregularities of the ſurface occaſioned by the veins in the wood. When the priming is quite dry a thin coat of gold-ſize muſt be laid on. This is prepared by grinding together ſome ſtrongly calcined red ochre with the thickeſt drying oil that can be procured, and the older the better: that it may work freely it is to be mixed, previouſly to being uſed, with a little oil of turpentine till it is brought to a proper conſiſtence. If the gold-ſize is good it will be ſufficiently dry in twelve hours, more or leſs, to allow the artiſt to proceed to the laſt part of the proceſs, which is the application of the

gold. For this purpoſe a leaf of gold is ſpread on the cuſhion (formed by a few folds of flannel ſecured on a piece of wood about eight inches ſquare by a tight covering of leather), and is cut into ſtrips of a proper ſize, by a blunt pallet-knife; each ſtrip being then taken up on the point of a fine bruſh is applied to the part intended to be gilded, and is then gently preſſed down by a ball of ſoft cotton; the gold immediately adheres to the ſticky ſurface of the ſize, and after a few minutes the dexterous application of a large camel's-hair bruſh ſweeps away the looſe particles of the gold-leaf without diſturbing the reſt. In a day or two the ſize will be compleatly dried, and the operation is finiſhed. The advantages of this method of gilding are that it is very ſimple, very durable, not readily injured by changes of weather even when expoſed to the open air, and when ſoiled it may be cleaned by a little warm water and a ſoft bruſh: its diſadvantage is that it cannot be burniſhed, and therefore wants the high luſtre produced by the next method. Its chief employment is in out-door work.

Burniſhed gilding, or gilding in diſtemper, is thus performed. The ſurface to be gilt muſt firſt be carefully covered with ſtrong ſize made by boiling down pieces of white leather, or clippings of parchment till they are reduced to a ſtiff jelly; this coating being dried, eight or ten more muſt be applied, conſiſting of the ſame ſize mixed with fine Paris-plaſter, or waſhed chalk; when a ſufficient number of layers have been put on, varying according to the nature of the work, and the whole is become quite dry, a moderately thick layer muſt be applied compoſed of ſize and bole, or yellow ochre: while this laſt is yet moiſt the gold leaf is to be put on in the uſual manner; it will immediately adhere on being preſſed with the cotton ball, and before the ſize is become perfectly dry thoſe parts which are intended to be the moſt brilliant are to be carefully burniſhed with an agate or dog's tooth. In order to ſave the labour of burniſhing it is a common but bad practice, ſlightly to burniſh the brilliant parts, and to deaden the reſt by drawing over them a bruſh dipped in ſize: the required contraſt between the poliſhed and unpoliſhed gold is indeed thus obtained, but the general effect is greatly inferior to that produced in the regular way, and the ſmalleſt drop of water falling on the ſized part occaſions a ſtain. This kind of gilding can only be applied on in-door work, as rain, and even a conſiderable degree of dampneſs will cauſe the gold to peel off. When dirty it may be cleaned with a ſoft bruſh and hot ſpirit of wine, or oil of turpentine. It is chiefly uſed on picture frames, mouldings, and ſtucco.

Letters written on vellum or paper are gilded in three ways: in the firſt, a little ſize is mixed with the ink, and the letters are written as uſual; when they are dry a ſlight degree of ſtickineſs is produced by breathing on them, upon which the gold leaf is immediately applied, and by a little preſſure may be made to adhere with ſufficient firmneſs: in the ſecond method ſome white lead or chalk is ground up with ſtrong ſize, and the letters are made with this by means of a bruſh: when the mixture is almoſt dry the gold leaf may be laid on and afterwards burniſhed: the laſt method is to mix up ſome gold powder with ſize, and make the letters of this by means of a bruſh. The edges of the leaves of books are gilded while in the binder's preſs by firſt applying a compoſition formed of four parts of Armenian bole and one of ſugar-candy ground together to a proper conſiſtence, and laying it on by a bruſh with white of egg: this coating when nearly dry is ſmoothed by the burniſher, it is then ſlightly moiſtened with clean water, and the gold leaf applied and afterwards burniſhed. In order to impreſs the gilt figures on the leather covers of books, the leather is firſt duſted over with very fine powdered roſin or maſtich, then the iron tool by which the figure is made is moderately heated, and preſſed down upon a piece of leaf-gold, which ſlightly adheres to it, being then immediately applied to the ſurface of the leather with a certain force, the tool at the ſame time makes an impreſſion, and melts the maſtich which lies between the heated iron and the leather; in conſequence of this the gold with which the face of the tool is covered is made to adhere to the leather, ſo that on removing the tool a gilded impreſſion of it remains behind.

Drinking glaſſes and other utenſils of this material are ſometimes, eſpecially in Germany, gilt on their edges: this is done in two ways, either by a ſimple adheſive varniſh, or by means of fire. The varniſh is prepared by diſſolving in drying linſeed oil a quantity of gum anime, or ſtill better, of clear amber equal in weight to the oil; a very drying and adheſive varniſh is thus prepared, which being diluted with a proper quantity of oil of turpentine is to be applied as thin as poſſible to thoſe parts of the glaſs which are to be gilded; when this is dry, which will be in about a day,

the glaſs is to be placed by the fire-ſide, or in a ſtove till it is ſo warm as almoſt to burn the fingers when handled; at this temperature the varniſh will become glutinous, and a piece of leaf gold applied in the uſual way will immediately adhere; when the gilding is thus put on and before it is grown quite cold it may be burniſhed, taking care only to interpoſe a piece of very thin paper between the gold and the burniſher. If the varniſh is very good this is the beſt method of gilding glaſs as the gold is thus fixed on more evenly than in any other way: it often happens however when the varniſh is but indifferent that by repeated waſhing the gold ſoon wears off: on this account the practice of burning in is ſometimes had recourſe to. For this purpoſe ſome powder-gold is tempered with gum-water and borax, and in this ſtate applied to the clean ſurface of the glaſs with a fine camel's hair pencil: when quite dry the glaſs is put into a ſtove heated to about the temperature of an annealing oven, the gum burns off and the borax by vitrefying cements the gold with great firmneſs to the glaſs; after which it may be burniſhed. The gilding upon porcelain is in like manner fixed by fire and borax; and this kind of ware being neither tranſparent nor liable to ſoften and thus injure its form in a low red heat, is free from the riſk and injury that the finer and more fuſible kinds of glaſs are apt to ſuſtain from ſuch treatment.

All the methods of gilding hitherto deſcribed reſemble each other by being accompliſhed by means of ſome adhefive medium; this, however, is not the caſe with gilding upon metals, the gold is brought into immediate contact with the other metal, and they both remain firmly united merely by the attraction of adheſion ſubſiſting between them. The ſimpleſt of all the kinds of gilding on metal, and which ſtrikingly demonſtrates the power of the affinity of adheſion is one that is ſometimes practiſed on plane ſurfaces of copper and iron with conſiderable ſucceſs. The metal being previouſly poliſhed and quite clean is heated to about the temperature of melted lead, and covered with a double layer of gold leaf: by the cautious application of a blood ſtone burniſher applied gently at firſt, and increaſing the force of the preſſure by degrees the ſurfaces of gold and copper are brought to touch each other in almoſt every point, and then adhere with a force proportioned to the compleatneſs of the contact. The firſt layer being thus burniſhed down a ſecond is made to adhere in the ſame manner, and ſometimes a third, if the gilding is intended to be very ſolid. The objection to this method of gilding is its tedioufneſs, and the almoſt impoſſiblity of uſing a ſufficient preſſure without injuring the evenneſs of the gilded ſurface: where theſe objections do not apply there cannot be a more effectual mode of gilding as is evident from the manufacture of gilt ſilver or copper wire. The bar before it is committed to the wire-drawer, is plated with gold by having ſeveral leaves of gold ſucceſſively burniſhed down upon it, and being then ſubjected to the ſtrong compreſſion that takes place in wire-drawing, the gold and the other metal become ſo perfectly united as to form in a manner but one ſubſtance.

The moſt uſual method of covering the ſurface of a metal with gold is by means of an amalgam, or as it is technically called *water-gilding*. If the metal to be gilt is ſilver, the beſt way of proceeding is firſt to ſoak it in warm dilute muriatic acid that the ſurface may be rendered perfectly clean; it muſt then be waſhed in clean water changed two or three times to get rid of the whole of the acid: being afterwards dried and made moderately warm a little gold-amalgam alſo warm is to be carefully and evenly ſpread upon the ſilver to which it will immediately adhere; when this is compleated the piece is placed upon a convenient ſupport over a clear charcoal fire, and while the mercury is evaporating if any ſpecks or places appear that have eſcaped the amalgam a ſmall piece is to be laid on and ſpread with a bruſh to ſupply the deficiency, without removing the article from the fire. After a time the whole of the mercury will be driven off, and the piece after cooling being accurately examined will be found to be entirely covered with a thin coating of pale dull gold. The ſmall roughneſſes and looſely adhering particles are now to be removed with a ſcratch bruſh, which is made of ſome exceedingly fine braſs-wire bound together into a tuft; by this the ſurface is rendered perfectly ſmooth and bright, but it ſtill remains of a pale yellow colour: this defect is next removed by warming the piece and ſmearing it over with gilder's wax, a compoſition of bees-wax, red ochre, verdigris, and green vitriol or alum. The wax being burnt off over a charcoal fire, and the piece quenched in urine the colour of the gilding will be found to be much heightened; if it is not ſufficiently ſo by the firſt application a ſucceeding one will compleat the deſired effect; after which the work may be burniſhed or not

according to the taſte of the artiſt. Inſtead of the common gilder's wax a mixture of equal parts of nitre, ſal ammoniac, green vitriol, and verdegris moiſtened with water, will anſwer the purpoſe.

Copper and the alloys formed by its combination with zinc are gilded nearly in the ſame way as ſilver: but as their affinity for mercury is conſiderably leſs than that of ſilver, it would be difficult to make the amalgam of gold adhere to the burniſhed ſurface of theſe metals by the ſame means, and with the ſame evenneſs as takes place in the caſe juſt deſcribed. To obviate this inconvenience advantage is very ingeniouſly taken of the action of nitric acid to facilitate the adheſion of the copper and mercury in the following manner. The piece of copper, a button for example, is firſt cleaned by ſteeping in acid and ſubſequent waſhing, and is then burniſhed either in a lathe, or by any other means: after this it is dipped in a neutralized ſolution of nitrat of mercury, and in the ſpace of a few ſeconds, owing to the ſtrong affinity of nitric acid for copper the mercurial ſalt is decompoſed, the copper takes the place of the mercury, and at the ſame time the mercury is depoſited in the metallic ſtate on the ſurface of the copper, covering it entirely, and ſtrongly adhering to it. The gold amalgam is now applied, and the reſt of the proceſs goes on as already deſcribed. By this method of proceeding a given quantity of gold may be made to cover a larger ſurface than in any other way of gilding on metals: five grains of gold will compleatly gild both the upper and under ſurfaces of 144 copper buttons, each of them an inch in diameter.[b]

There is no metal the gilding of which preſents ſo many difficulties as iron, or rather ſteel. If the method of ſimple burniſhing down is had recourſe to, the heat requiſite for this purpoſe will in many caſes bring the temper of the ſteel too low: on ſuch occaſions the way already deſcribed of gilding copper is ſometimes practiſed; that is, the parts of the ſteel to be gilded are pencilled over with nitrat of mercury, by which they are covered with a ſlightly adhering coating of mercury, then the amalgam is applied, and the gilding finiſhed in the uſual way. The objections to this mode of proceeding are firſt that a conſiderable heat is required, though inferior to that requiſite for burniſhing down, and ſecondly, that even with all poſſible care the gilding is apt to be rough and ſcale off. A very conſiderable improvement on this method is to trace the figure of the gilding on the ſteel firſt of all with a bruſh charged with a ſtrong ſolution of ſulphated copper, in conſequence of which a pretty thick plate of this metal is depoſited on the ſteel to which it may be made to adhere with conſiderable firmneſs by means of the burniſher: thus the gilding is in fact performed upon the copper.

A new method of gold gilding upon ſteel has lately been publiſhed [c] poſſeſſed of many advantages over the others, and which probably in time may attain a very high degree of perfection. It depends upon the well-known fact that if ſulphuric ether and nitro-muriat of gold are mixed together the ether will by degrees ſeparate from the acid nearly the whole of the gold, and retain it for ſome time in ſolution in nearly a metallic ſtate. If ether thus charged with gold is ſpread by means of a pen or fine bruſh on the ſurface of highly poliſhed ſteel the ether preſently evaporates, leaving the gold behind in cloſe contact with the ſteel, and the adheſion is conſiderably improved by the ſubſequent application of the burniſher. The dearneſs, and eſpecially the rapid volatility of ether are objections of ſome moment, but may be got over by uſing the beſt oil of turpentine inſtead of the ether, which has nearly the ſame efficacy in decompoſing the nitro-muriat of gold, and is both cheaper and not ſo very quickly evaporable.

Cold gilding upon ſilver is, we believe, at preſent entirely diſuſed. It was performed in the following manner. A ſaturated ſolution of gold in nitro-muriatic acid was poured upon ſome linen rags, and when they were become dry they were heaped in a plate and touched with a hot coal. The fire gradually ſpread through the maſs and reduced it to a heavy black aſh. A ſoft cork being moiſtened in water was dipped in this aſh, to which a part of it adhered, and was then rubbed on the ſurface of poliſhed ſilver, upon which the minute particles of gold became fixed, and covered it with an extremely thin coating, which when burniſhed exhibited the genuine colour and luſtre of this precious metal.

GLASS. *Verre*, Fr. *Glas*, Germ.

A glaſs in the common chemical uſe of the term is underſtood to be any ſubſtance or mixture, earthy, ſaline, or metallic, brought by igneous fuſion to the ſtate of a hard, brittle, uniform maſs, breaking with a conchoidal fracture, paſſing into ſplintery, and with a high degree of luſtre. Tranſparency is alſo a cha-

[b] Phil. Mag. ix. p. 20.

[c] Phil. Mag. xi. p. 144.

racter of moſt glaſſes, for when opake, it is generally owing to an exceſs of ſome matter, which, in a ſmaller quantity, would only give a tinge of more or leſs denſity.

Beſides the general acceptation of the term glaſs, it is alſo applied more commonly to that moſt beautiful manufacture of ſiliceous earth, vitrified by various ſalts and metallic oxyds, which contributes ſo much to the purpoſes of ſcience, to ornament, luxury, and to domeſtic comfort.

We ſhall firſt ſhortly give the reſults of a variety of experiments on *Vitrification* in general, and afterwards deſcribe the manufacture of glaſs.

VITRIFICATION.

An immenſe repoſitory of valuable facts on vitrification is to be found in the voluminous experiments of Mr. Achard, of Berlin,[a] from which, together with the later experiments of Kirwan,[b] Klaproth,[c] Morveau,[d] and other chemiſts, the following facts may be deduced. It may be premiſed that in all theſe experiments the mixtures were firſt reduced to fine powder, well mixed, put into a crucible, and expoſed to nearly as ſtrong a heat as the power of furnaces will give. Thoſe of Achard were uſually introduced into the porcelain furnaces of the royal porcelain manufactory of Berlin; of Klaproth, the ſame; of Kirwan and Morveau, in a wind furnace of very powerful draught, the intenſity of which was in moſt caſes marked by Wedgewood's pyrometer. The effects produced by the action of the materials on the crucible itſelf will be preſently noticed.

§ 1. *Of the Vitrification of Earths alone.*

All the earths are of themſelves infuſible by any heat except that of a blaſt of oxygen gas, as aſcertained by Lavoiſier. Hence infuſibility in culinary fire is properly given as a character of earthy bodies. But various mixtures of earths alone may be vitrified with more or leſs eaſe.

Of the binary combinations of earths none are vitrifiable except thoſe in which one of the ingredients is lime or barytes (and probably ſtrontian), and in equal proportion with the other, and at a very intenſe heat.

Theſe earths therefore agree with the alkalies in their vitrifying power as well as in other alkaline properties, and like the alkalies this power is more active in diſſolving ſilex than alumine or magneſia.

Silex and lime, in equal parts (according to Kirwan) melted at 150° of Wedgewood, into a maſs between porcelain and enamel, white, glazed at the ſurface, ſemitranſparent at the edges, and feebly giving fire with ſteel.

Silex and barytes, in equal parts, (by Kirwan) gave at 148° Wedgewood, a hard maſs not melted, but (by Morveau) melted into a green glaſs exceſſively hard and cellular. Two parts of barytes and one of ſilex gave (by Kirwan) a yellowiſh green porous enamel at 150°.

Silex with alumine, or with magneſia ſingly, and in any proportion, gave only a ſlightly cohering crumbly maſs ſcarcely altered by the fire except in the parts touching the crucible.

Alumine and magneſia heated with the alkaline earths in any proportions gave only ſlightly agglutinated maſſes, but would not melt into a glaſs or even an enamel.

The alkaline earths mixed together fuſed more readily than any of the above mixtures, forming very perfect glaſſes, but which almoſt immediately begin to attack the ſides of the crucible, and melt down with it in a ſtrong fire into a vitreous ſlag.

With regard to combinations of three or more earths it would be endleſs to enumerate all the poſſible or actual experiments. Kirwan deduces from thoſe which he made the following general reſults, which indeed might partly be expected from the known properties of the ſeveral earths: namely,

No compound of lime, magneſia, and alumine, in which the magneſia predominates will melt at a leſs heat than 160°: and to produce compleat vitrifaction, the lime (which is properly the flux in this inſtance) muſt be equal to the two others. Where either the magneſia or alumine predominate the maſs forms a porcelain, or imperfect glaſs.

In compounds of lime, magneſia, and ſilex, if the lime exceeds, perfect glaſſes will be formed, if the ſilex exceeds, few glaſſes will be formed, and never, if the magneſia exceeds.

In compounds of alumine, magneſia, and ſilex, the reſults are ſo far curious, that a porcelain, and even a perfect glaſs, may be produced in the proportions of 3 ſilex, 2 magneſia, and 1 alumine. The ſilex therefore here ſeems to act as a powerful flux, for when either of the two latter exceed, ſcarcely any approach to fuſion can be obtained.

It follows, therefore, that the more fuſible earths, of thoſe here examined, when in mixture, are lime, and eſpecially barytes, and next to them ſilex, and that alumine and magneſia are remarkably difficult of fuſion in mixture,

[a] Mem. Acad. Berlin, for 1779, 1780, 1781. [b] Mineralogy. [c] Eſſays, vol. 4. [d] Jour. Polytech. p. 3.

and according to their predominance give opake white maſſes of a cellular, ſpongy, ſemi-fuſed texture; or in greater proportions, only porcellanous; or in greater, only looſely coherent and pulverulent.

§ 2. *Of the Vitrificaion of Earths by Metallic Oxyds.*

All the metallic oxyds that are not reduced by mere heat to the reguline ſtate or volatilized, when urged by fire, run into a true glaſs which is always more or leſs tinged, and often poſſeſſes ſuch a body of colour as to be quite opake. The heat at which the oxyds vitrify varies extremely, in no inſtance is it leſs than a red heat, and in many a very intenſe white heat is required. All the vitrified oxyds are powerful fluxes for the earths, though leſs in proportion than the alkalies. They give their own colour to the vitrified mixture and much denſity.

The vitrifying power of ſeveral of the oxyds over the different earths has been examined in a ſeries of valuable experiments by Achard, of which the following table will furniſh an abſtract. It may be premiſed that the ſilex was prepared from liquor of flints, and apparently very pure, the calcareous earth was carbonat of lime precipitated from the muriat by a carbonated alkali; the magneſia from Epſom ſalt in the ſame way, and the alumine from alum. The oxyd of copper was the green carbonated oxyd prepared from the nitrat by carbonat of potaſh; the oxyds of iron, lead, and zinc, the ſame; the oxyds of tin, biſmuth, and antimony were alſo prepared by nitric acid, and therefore in the higheſt ſtate of oxygenation.

All theſe mixtures were expoſed in earthen crucibles to the heat of a porcelain furnace during the whole time required to bake the porcelain.

Mixture.	*Result.*	*Colour and Texture.*
Silex . . . . 1 Oxyd of iron. . 1.	ſcoria	black and poliſhed—hard, giving ſparks with ſteel.
Silex . . . . 2 Oxyd of iron . 1.	not fuſed	black and friable.
Silex . . . . 1. Oxyd of iron . . 2.	ſcoria run through the crucible	black and hard—ſcintillant.
Silex . . . . 1 Oxyd of copper . 1.	not fuſed	
Silex . . . . 1. Oxyd of copper . 4.	not fuſed	
Silex . . . . 1 Oxyd of lead . . 1.	a ſolid maſs but not fuſed	white and hard
Silex. . . . . 1. Oxyd of lead . 2	fuſed, porous, and ſemi-vitrified	yellow—not ſcintillant.
Silex . . . . 1 Oxyd of lead . 3	perfect glaſs	green—not ſcintillant.
Silex . . . . 1 Oxyd of tin . . 1.	a coherent maſs	grey—eaſily friable.
Silex . . . . 1 Oxyd of tin . . 2.	vitrified	greeniſh yellow—not ſcintillant.
Silex . . . . 1 Oxyd of biſmuth 1.	remained in powder	
Silex . . . . 1 Oxyd of biſmuth 4.	perfect glaſs	deep yellow—not ſcintillant.
Silex . . . . 1. Oxyd of antimony 1.	glaſs	colourleſs—ſcintillant.
Silex . . . . 2 Oxyd of antimony 1.	not melted	grey and friable.
Silex . . . . 1. Oxyd of zinc . 1.	remained in powder	
Silex . . . . 1. Oxyd of zinc . 2.	melted only where touching the crucible	white—hard.

Mixture.	*Result.*	*Colour and Texture.*
Silex . . . . 1. Oxyd of zinc . 3.	perfectly fused	grey—ſcintillant.
Lime (carbonated) 1 Oxyd of iron . 1.	a melted porous maſs	black—ſcintillant.
Lime . . . . 1 Oxyd of copper . 1.	melted, poliſhed in the fracture, part of the copper reduced	red—ſcintillant.
Lime . . . . 3 Oxyd of copper . 1.	melted, but porous	the ſame.
Lime . . . . 4 Oxyd of copper . 1.	part only melted, the reſt pulverulent	grey.
Lime . . . . 1 Oxyd of lead . 1.	glaſs	greeniſh yellow—ſcintillant.
Lime . . . . 2 Oxyd of lead . 1.	glaſs run through the crucible	yellow—ſcintillant.
Lime . . . . 3 Oxyd of lead . 1.	remained in powder	
Lime . . . . 1 Oxyd of tin . . 1.	ſemi-vitrified	yellow—ſcintillant.
Lime . . . . 2. Oxyd of tin . . 1.	glaſs	greeniſh yellow—ſcintillant.
Lime . . . . 3 Oxyd of tin . . 1.	melted only where touching the crucible	grey.
Lime . . . . 4 Oxyd of tin . . 1.	glaſs	greeniſh yellow—ſcintillant.
Lime . . . . 1 Oxyd of biſmuth 2	vitriform maſs	green.
Lime . . . . 1 Oxyd of antimony 1.	glaſs penetrating the crucible	yellow—ſcintillant.
Lime . . . . 2 Oxyd of antimony 1	remained in powder	
Lime . . . . 1 Oxyd of antimony 4	glaſs penetrating the crucible	deep yellow—ſcintillant.
Lime . . . . 4 Oxyd of antimony 1.	a ſemi-tranſparent poliſhed maſs	grey yellow—ſcintillant.
Lime . . . . 1 Oxyd of zinc . 1.	glaſs	deep yellow—ſcintillant.
Alumine . . . 1 Oxyd of iron . 1.	only partially fuſed	
Alumine . . . 1. Oxyd of iron . 3.	a melted porous maſs	black—ſcintillant.
Alumine . . . 1. Oxyd of copper . 1.	only partially fuſed	
Alumine . . . 1 Oxyd of copper . 4.	the ſame	
Alumine . . . 1. Oxyd of lead . 1.	remained in powder	
Alumine . . . 1. Oxyd of lead . 3.	the ſame	
Alumine . . . 1 Oxyd of lead . 4.	glaſs	deep yellow—ſcintillant.

Mixture.	*Result.*	*Colour and Texture.*
Alumine . . . 1 Oxyd of tin . . 2	a melted porous mafs, not polifhed in the fracture	grey—fcintillant.
Alumine . . . 1 Oxyd of bifmuth 2.	partially fufed	
Alumine . . . 1 Oxyd of antimony 4.	only partially fufed	
Alumine . . . 1. Oxyd of Zinc . 4.	remained in powder	
Magnefia . . . 1 Oxyd of iron . 3.	half fufed, but not cohering	
Magnefia . . . 1 Oxyd of copper . 3	a porous half-fufed mafs	grey—fcintillant.
Magnefia . . . 1. Oxyd of lead . 3	not fufed	
Magnefia . . . 1 Oxyd of lead . 4.	a porous melted mafs, part of the oxyd reduced	
Magnefia . . . 1 Oxyd of antimony 3.	beginning to fufe.	grey—fcintillant.

The above experiments (felected from a much larger number) are moftly confirmed by Kirwan. Notwithftanding various anomalies, owing principally to the action of the materials on the crucible itfelf, they are intereffing in fhewing in fome degree the comparative fufibility of metallic oxyds, and in confirming the former obfervations on the fufibility of the refpective earths. Among the metallic oxyds that of antimony feems to act the moft powerfully as a flux, and next to this, lead. In almoft all the above examples where fufion at all took place, the mafs became hard enough to ftrike fire with fteel, a degree of hardnefs which is not very common with the alkaline glaffes.

§ 3. *Of the Vitrification of Earths with Saline Bodies.*

We fhall here alfo give in a tabular form a few of the numerous experiments of Achard (A) and of Morveau (M) premifing that in each the mixture of the earths and falts was contained in a clay crucible which was always acted on more or lefs during the vitrification, and where the falt was in excefs was often entirely corroded, a circumftance which throws fome confufion on the refults. In the experiments of Achard the crucibles were expofed for three hours to the heat of a very ftrong wind furnace: in thofe of Morveau the crucibles were kept for two hours at a heat of from 22 to 26 Wedgwood, and therefore probably much lower than the former.

	Mixture.	*Refult.*
A.	Silex . . . . . 1 Carbonat of potafh . . . . 1.	a yellow glafs, not hard enough to give fparks with fteel.
M.	Silex . . . . . 1 Carbonat of foda (dry) . . 2.	a colourlefs tranfparent glafs, but deliquefcent from the excefs of alkali.
A.	Silex . . . . . 3 Carbonat of potafh . . . . 1.	a yellow glafs, not fcintillant.
A.	Silex . . . . . 4 Carbonat of potafh . . . . 1.	a vitriform mafs, yellow, hard, and fcintillant.
M.	Silex . . . . . 1 Borax (calcined) 2	a beautiful tranfparent glafs, not at all foluble in water.
A.	Silex . . . . . 1 Boracic acid 1	a white porcellanous mafs, fcarcely fcintillant.

	Mixture.		*Result.*
A.	Silex	1	a hard tranſparent glaſs—ſcintillant.
	Boracic acid	2	
A.	Silex	4	a white opake melted porous maſs—ſcintillant.
	Boracic acid	1.	
A.	Silex	3	a tranſparent glaſs—hard and ſcintillant.
	Calcined borax	1.	
A.	Silex	4	a maſs reſembling agate—but perfectly fuſed and ſcintillant.
	Calcined borax	1.	
A.	Silex	2	a green ſcintillant glaſs.
	Sulphat of ſoda	1.	
A.	Silex	3	a ſoft green tranſparent glaſs.
	Nitre	1.	
A.	Silex	1.	ſcoria—the crucible entirely deſtroyed.
	Common ſalt	2.	
M.	Silex	1.	a white opake, puffy, vitreous maſs, deliqueſcent and reddening litmus.
	Phoſphat of ſoda and ammonia	2.	
M.	Lime	1	a white ſpongy opake maſs, crumbling between the fingers.
	Carbonat of ſoda	2.	
A.	Chalk	2	partly fuſed—the reſt pulverulent—the crucible ſtrongly corroded.
	Carbonat of potaſh	1.	
A.	Chalk	1	a well-fuſed, poliſhed, black ſcintillant glaſs.
	Carbonat of potaſh	2.	
A.	Chalk	4	remained a white powder.
	Carbonat of potaſh	1.	
M.	Lime	1	a fine tranſparent yellowiſh glaſs—the crucible ſtrongly corroded.
	Borax	2	
A.	Chalk	4	a well-fuſed, black, ſcintillant poliſhed maſs.
	Borax	1.	
A.	Chalk	3	a yellow ſcintillant glaſs.
	Borax	1.	
A.	Chalk	1.	a yellow glaſs—run through the crucible.
	Boracic acid	2.	
A.	Chalk	3.	a hard yellow ſcintillant glaſs.
	Sulphat of ſoda	1.	
A.	Chalk	1	a hard brown ſcoria—the crucible totally deſtroyed.
	Sulphat of ſoda	4.	
A.	Chalk	1.	a hard yellow glaſs.
	Nitrat of ſoda	1	
A.	Chalk	1.	a yellow ſcintillant glaſs—the crucible entirely deſtroyed
	Common ſalt	1.	
M.	Lime	1.	a white opake crumbly maſs.
	Phoſphat of ſoda and ammonia	2	
M.	Alumine	1	a grey opake ill-fuſed frit, not cohering to the crucible and deliqueſcent.
	Carbonat of ſoda	2.	
A.	Alumine	4	remained unmelted and uncohering.
	Carbonat of ſoda and potaſh in all proportions from 1 to 12.		
A.	Alumine	1.	partially melted, but ſoft and friable.
	Carbonat of potaſh	4.	

	Mixture.		Result.
M.	Alumine	1.	a fine tranſparent clear green glaſs.
	Borax	2.	
A.	Alumine	1	remained pulverulent.
	Borax	1.	
A.	Alumine	1.	part unfuſed and remaining pulverulent, the reſt partially melted.
	Boracic acid	4.	
M.	Alumine	1	a green frit eaſily friable.
	Phoſphat of Soda and Ammonia	2	

N. B. Moſt of the other combinations of alumine with the ſeveral neutral ſalts, even in large proportions of the latter, remained unfuſed, except where the crucible was entirely corroded and melted down along with its contents.

M.	Magneſia	1	a white opake incohering maſs.
	Carbonat of ſoda	2.	
M.	Magneſia	1	a ſemi-tranſparent ſomewhat milky glaſs of a gelatinous appearance, but very hard and brilliant on the ſurface.
	Borax	2.	
M.	Magneſia	1.	a white maſs a little agglutinated but not adhering to the crucible.
	Phoſphat of Soda and Ammonia	2.	
M.	Barytes (pure)	1	a very hard ſemi-vitrified maſs, of a clear green.
	Carbonat of ſoda	2	
M.	Barytes	1	a beautiful tranſparent glaſs with a faint yellow tinge, ſtrongly adhering to the crucible
	Borax	2.	
M.	Barytes	1	a remarkably fine tranſparent glaſs.
	Phoſphat of Soda and Ammonia	2.	

§ 4. *Of the Action of Vitrifying Materials on the Crucibles that contain them.*

In eſtimating the proper action of vitrifiable ſubſtances on each other, the nature of the veſſels that contain them ſhould always be taken into account, as a want of this precaution may readily lead to the moſt erroneous concluſions. The celebrated Pott ſeems to have been the firſt who very diſtinctly pointed out this circumſtance, and ſeveral curious experiments have been made by Gerhard,[e] which deſerve further notice.

This able chemiſt expoſed a variety of natural minerals to a very high heat (that is fully equivalent to that at which caſt iron melts) for an hour, under circumſtances as exactly ſimilar as poſſible, except with this difference, that one ſpecimen of each mineral was incloſed in a crucible of clay, another in one of chalk, and a third in one of charcoal, and the difference in the reſult was particularly noticed. A few of theſe may alſo be given in a tabular form.

[e] Mem. Acad. Berlin, for 1781.

Subſtance uſed.	*Reſult in the Clay crucible* (A)	*Reſult in the Chalk crucible* (B)	*Reſult in the Charcoal crucible* (C.)
Common flint	opake and milk-white, but without fuſion	opake and white, but with beginning fuſion where in contact with the crucible	as in A.
Marble	run into a green glaſs	no change	no change.
Gypſum	run into a radiated green glaſs	no change	no change.
Fluor ſpar	melted and ran through the crucible	melted down with the crucible to a tough flag	ſcarcely altered, except ſlight fuſion at the edges.
Porcelain clay	compact, white and no ſigns of fuſion	run into a hard blue clear glaſs	as in A.
Ditto, another kind	a compact maſs partially melted	a perfectly black glaſs	as in A.
Reddle	a black glaſs covered with a cruſt of reduced iron	a ſemitranſparent apple-green glaſs	a brown ſcoria containing grains of iron
Jaſper	no fuſion, but the colour changed to brown	compleatly fuſed in the parts touching the crucible	as in A.
Muſcovy talc	a black glaſs with interſperſed grains of iron	the whole crucible was penetrated with a ſcoria ſo as not to fall to powder on expoſure to air	as in A.
Spaniſh chalk	only hardened	a grey ſemitranſparent glaſs	as in A.
Baſalt	brown-yellow glaſs with a cruſt of iron	a green ſcoria, alſo with a cruſt of iron	a green glaſs with many grains of iron.

In all the above experiments, except in that with the Muſcovy talc, the chalk crucible was completely calcined to lime and fell into powder like common lime on expoſure to air. The difference therefore between the action of the clay crucible and that of chalk, both reſpects the different fuſibility of common clay and lime, and whatever action the carbonic acid that is eſcaping from the chalk may have upon the incloſed materials.

Similar and very valuable experiments have been repeated by Profeſſor Klaproth in crucibles of clay and of charcoal, in which theſe differences are very ſtriking.

Some of the moſt illuſtrative of them are the following.

White alabaſter.

(In the charcoal crucible.) Was rendered moderately hard, its colour was white paſſing to ſtraw yellow, with a fine grained earthy fracture, it adhered to the tongue and emitted an odour like a ſulphuret; loſs of weight .56.

(In the clay crucible.) Gave a black-brown glaſs, very ſhining, little tranſparent on the edges.

Baſalt.

(In charcoal crucible.) Fuſed into a compact brown glaſs, tranſparent in ſplinters. Externally partly glazed brown, partly covered with a ferruginous cruſt, and large grains of iron.

(In clay crucible.) Gave a ſolid black glaſs covered with a brown ſteel-grey veined iron cruſt.

Bohemian garnet.

(In charcoal crucible.) Gave a grey turbid glaſs full of grains of iron.

(In clay crucible.) Melted into an opake almoſt compact ſcoria, whoſe colour internally changed by ſtripes from brown to green, very finely corroded.

Hornblende.

(In charcoal crucible.) A hardened ill-ſhaped maſs with grains of iron. Colour light-grey, fracture uneven, without any trace of vitrification,

(In clay crucible.) Melted into a denſe black-brown glaſs, tranſparent in the fragments; of a ſmooth ſurface and a flat conchoidal, gloſſy fracture.

Carrara marble.

(In charcoal crucible.) Was converted into quick-lime.

(In clay crucible.) Changed into a denſe, clear, hard, pale, graſs-green glaſs.

Strontianite.

(In charcoal crucible.) Form unaltered: hardened by ignition, rendered dull and very cauſtic: loſs of weight 0.31.

(In clay crucible.) A clear bright graſs-green glaſs.

Witherite.

(In charcoal crucible.) In repeated experiments the charcoal crucible was found for the moſt part conſumed. Hence the witherite always entered into imperfect fuſion with the contiguous part of the clay-crucible, which ſerved as a caſe to the charcoal crucible.

(In clay crucible.) A green ſomewhat muddy, frothy glaſs.

In ſpeaking therefore of the fuſibility of all vitrifiable mixtures, the nature of the veſſel that contains them ſhould always be taken into account, ſo that as Klaproth has well obſerved, the uſual diviſion of earths and ſtones into fuſible and infuſible requires correction from this circumſtance. Thus when ſtrontianite, marble, and in general all ſpecies of calcareous earth vitrify in the melting veſſels, it is entirely owing to the mutual action of the earth and the clay crucible, ſince they remain unfuſed in the charcoal crucible.

The charcoal alſo it will be obſerved in theſe experiments has often opportunity of acting in the uſual manner of carbonaceous mixtures, as in reducing gypſum to a ſulphuret of lime, and aſſiſting in the calcination of the carbonats of lime, ſtrontian, and barytes.

It alſo has another action which tends to diminiſh the natural fuſibility of ſtones, and this is the reduction of the iron contained in them, which, when an oxyd, is itſelf a powerful flux. Hence it is that ſeveral ſtones naturally fuſible will not vitrify in a charcoal crucible, of which the baſalt is an example, as this mineral readily melts *per ſe* into a black glaſs; but when in contact with charcoal, the oxyd of iron is reduced, and globules of metallic iron ſweat out as it were, or ſeparate by a kind of eliquation, and the baſalt then appears, if examined by a lens, almoſt wholly corroded but not changed into a ſcoria or at all vitrified, except by a much more intenſe and long continued heat. This ſeparation of the iron by charcoal, as Klaproth further remarks, takes place even in thoſe ſtones which hardly appear to ſoften in the fire, and yet the globules of iron exude on the ſurface.

The colour of earths when perfectly vitrified and not in contact with charcoal, is for the moſt part of a cold ſea-green paſſing into emerald green, and ſometimes with a tinge of brown, where the glaſs is at all tranſparent. This is alſo obſervable in the common bottle glaſs, and thoſe vitreſcent mixtures where unpurified aſhes are employed inſtead of pure alkali. This colour appears to be entirely owing to the preſence of iron, which is always contained more or leſs in common clays and in vegetable aſhes, as was diſcovered by Scheele, who obtained a ſatisfactory indication of this metal in the analyſis of a green ordinary glaſs.

Some experiments of Mr. Muſhet[f] on the affinities of the different earths for carbon at exceſſively high heats, ſhew in a ſatisfactory manner the gradual change produced on this natural green colour by the admixture of charcoal in various doſes. A few of theſe we ſhall relate.

1. Some lime from calcined chalk was heated without addition in a crucible of Stourbridge clay, at a heat of 166° Wedgewood, and fuſed into a perfect denſe glaſs, quite tranſparent and of a green approaching to emerald.

2. Fifty grains of the ſame lime were mixed with 1 grain of lamp black (a very pure carbon) and fuſed as before. The reſult was a lead-blue greeniſh colour. The charcoal had diſappeared, but no globules of reduced iron could be obſerved.

3. Fifty grains of lime with $2\frac{1}{2}$ of charcoal gave a denſe glaſs, of a dark lead-blue. Part of the charcoal remained uncombined with the glaſs, and a number of globules of iron were revived.

1. A cryſtal of double refracting ſpar was melted *per ſe* as before into a very perfect glaſs of a rich green amber colour.

2. Twenty grains of the ſame ſpar mixed with one grain of charcoal fuſed into a deep fiery amber-coloured glaſs. All the charcoal had diſappeared.

3. Twenty grains of the ſame ſpar with $1\frac{1}{2}$ grain of charcoal melted into a glaſs of a cloudy milky lead-colour. A minute portion of the charcoal remained and many globules of iron were ſeen on the ſurface.

[f] Phil. Mag. vol. 18.

From theſe experiments it appears that any admixture of carbon below what is neceſſary to reduce the iron only alters the ſhade of colour, giving in ſome inſtances an amber red, in others a dull lead-blue, which is poſſibly in part owing to an actual combination of the charcoal with the glaſs, but more probably to be chiefly aſcribed to a partial diſoxygenation of the oxyd of iron contained in the earth; as numerous experiments which will be afterwards noticed ſhew that the colouring power of all the metallic oxyds is materially affected by the degree of oxygenation. But when the charcoal is ſufficient entirely to deoxygenate the iron the tranſparency of the glaſs is deſtroyed, and the colour is a muddy blue, like that of a partially reduced vitrified iron ore.

It is ſtill doubtful whether carbon has any real affinity for any of the earths in a vitrified ſtate, that is, whether the carbon is properly *diſſolved* in the earthy glaſſes or only *diffuſed* through them in a ſtate of very minute diviſion. In all Mr. Muſhet's experiments with the other earths and carbon, where the latter was in any exceſs above what might be ſuppoſed neceſſary merely to deoxygenate the iron, the reſulting glaſs received pretty uniformly a more or leſs deep tinge of muddy lead or ſlate-blue, which appears much more like a mere diffuſion of the carbon through the glaſs than a perfect ſolution in it.

Some geological remarks on the ſubject of *Vitrification* will be noticed under that article, and we now proceed to the manufacture of Glaſs.

Glass invariably contains two eſſential ingredients, ſilex, and an alkali, either potaſh or ſoda, and theſe are all that are abſolutely neceſſary for its compoſition, but other acceſſary ſubſtances are alſo uſed for particular purpoſes, among which may be particularly mentioned lime in the form of chalk, borax, oxyd of lead, oxyd of manganeſe, white oxyd of arſenic and nitre. Each of theſe requires ſome ſeparate notice.

The *Silex* may be obtained from various ſources, and of different degrees of purity, according to the fineneſs of the glaſs required. The ſiliceous material almoſt univerſally uſed in this country is ſea ſand, which is well known to conſiſt of minute rounded grains of quartz, and is already ſufficiently ſmall to be uſed without any other preparation than that of waſhing. The fineſt ſand is ſaid to come from near Lynn on the coaſt of Norfolk, and alſo from the weſtern extremity of the Iſle of Wight. Another equally pure kind of ſilex is the common black gun-flints, which before uſing muſt be heated red-hot and immediately quenched in cold water. The heat whitens them, and the water ſplits them in every direction, by which means they may afterwards be ground in mills without much difficulty. But this ground flint though largely uſed in the potteries in this kingdom, is ſcarcely ever employed in glaſs-making. The rounded lumps of white quartz found ſo abundantly in the beds of rivers in many mountainous diſtricts, are ſometimes uſed in foreign countries for this purpoſe, being firſt heated and ground to powder.

The *Alkali* uſed in this manufacture is either ſoda or potaſh, each being apparently equally well fitted for the purpoſe. It is always uſed at firſt in the ſtate of carbonat, though the carbonic acid flies off in the proceſs, for glaſs is a compound of ſilex and alkali, and not alkaline carbonat. Theſe alkalies are uſed in every degree of purity according to the required quality of the glaſs. For the fineſt flint-glaſs the beſt pearlaſhes purified by ſolution and evaporation to dryneſs are employed, but the inferior glaſſes are made with the coarſer alkalies, with barilla where this alkali is cheap, with common wood-aſhes, and very largely with kelp. Though theſe alkalies are very impure, this does not prevent their diſſolving the ſilex into a very good and perfect glaſs, for the impurities partly conſiſt of neutral ſalts and partly of lime and other earths, all of which aſſiſt in the vitrification. Glaſs made from theſe alkalies has always more or leſs of a green tinge as in the common bottle-glaſs, owing to the preſence of iron contained in theſe aſhes. The methods of purifying and preparing theſe alkalies are deſcribed under the *Carbonats* of the reſpective alkalies.

Lime when employed in glaſs-making is generally uſed in the form of chalk. The property of lime and the other alkaline earths in promoting the vitrification of ſilex has been already mentioned, and ſhewn to be very powerful, though leſs ſo than that of the alkalies. Lime is uſed only in ſmall proportions in the glaſs-pots, for the eſcape of the carbonic acid from the chalk during the fuſion cauſes the materials to ſwell to an inconvenient degree; and alſo if the lime is in exceſs it acts very powerfully on the ſides of the pots. Beſides, an over proportion renders the glaſs opake and milky on cooling though quite clear when hot. Experience has ſhewn that to 100 parts of ſilex with the requiſite quantity of alkali, no more than about 6 or 7 of quick lime can be added

(or chalk in proportion) without endangering the clearneſs of the glaſs. The particular uſe of this ingredient, beſides that of affording a very cheap flux, is to render the glaſs eaſier to work and leſs liable to crack by ſudden changes of temperature.

Borax is perhaps the moſt powerful and valuable flux that is known. On account of its high price it is not uſed in any of the common glaſſes, but is employed in the fineſt kinds of plate glaſs and thoſe articles that are required to be particularly clear and free from ſpecks and bubbles. It is peculiarly well fitted for this purpoſe, as it renders all vitreſcent compounds into which it enters remarkably thin-flowing, and therefore beſt adapted for being caſt in a mould, which is the way in which theſe articles are manufactured. A very ſmall quantity of borax will correct any deficient ſtrength in the alkali.

The oxyds of lead, of which *litharge* and *minium* are the only ones employed in the large way, are of ſingular uſe in glaſs-making. Litharge melts *per ſe* into a very denſe clear yellow tranſparent glaſs, remarkably ſoft and unctuous to the touch, fuſible at a very low red heat, and when melted acting ſo powerfully on all earthen veſſels as to run through the common porous crucibles in a very ſhort time, almoſt like liquor through a ſieve, but vitrifying and corroding the bottom of the crucible in its paſſage. Litharge is therefore a moſt powerful flux to all earthy mixtures, and it imparts to glaſs the valuable qualities of greater denſity and greater power of refracting the rays of light, and of bearing ſudden changes from heat to cold without being ſo liable to crack, and alſo greater tenacity when red-hot, and therefore eaſier to be worked.

Moſt of the finer glaſſes contain a conſiderable quantity of this oxyd, particularly the London flint glaſs, or that ſort which is uſed for moſt of the purpoſes of the table, for luſtres and other ornamental works, which when cut into various forms diſplay ſo beautiful a play of light, for artificial gems, and for moſt optical purpoſes. Glaſs containing much lead has, however, the great defect of being extremely ſoft ſo as to be readily ſcratched and injured by almoſt every hard body it rubs againſt. It is alſo extremely fuſible, ſo that thin tubes of it will bend with eaſe in the flame of a candle, and will ſink down into a ſhapeleſs maſs at a very moderate red-heat. This quality for chemical purpoſes is ſometimes an advantage, ſometimes the contrary. When the lead is in exceſs there is alſo ſome danger of the glaſs being corroded by very acrid liquors. Another defect alſo attending the uſe of lead is the extreme difficulty of uniting it ſo intimately with the ſilex and alkali that a whole piece of glaſs wrought with it ſhall be of equal denſity throughout, as the litharge on account of its much ſuperior denſity is always liable to ſink towards the bottom of the glaſs-pots before it can be detained by the other ingredients. This inequality ſubſiſts throughout, ſo that every ſtratum of the melted maſs is of intermediate denſity between the ſtratum above and that below, which is apt to occaſion *waves* in the glaſs when wrought, ſuch as appear when water is gently poured on ſulphuric acid, without mixing, and the veſſel ſlightly agitated. This defect is particularly felt in ſome optical purpoſes where a certain thickneſs of glaſs is uſed.

The black oxyd of manganeſe was uſed in glaſs making long before its preciſe nature was underſtood. Its ancient name of *glaſs ſoap* denotes its particular uſe, namely, that of clearing the glaſs from any accidental foulneſs of colour which it would otherwiſe contract from the impurity of the alkali, or other materials employed, and eſpecially the green tinge, owing as already mentioned, to the preſence of iron.

Many curious circumſtances attend the uſe of manganeſe in glaſſes, which have been beautifully illuſtrated by the reſearches of Scheele [a] and Bergman. [b] They are the following (accommodating the explanation given by theſe illuſtrious chemiſts to the antiphlogiſtic theory.)

When the oxyd of manganeſe is fuſed with any ſimple glaſs ariſing from any admixture of ſilex and alkali, or with borax and microcoſmic ſalt, the reſult is a glaſs of more or leſs of a violet-purple colour, which when the manganeſe is at all in conſiderable quantity is ſo deep as to be almoſt entirely black. By this fuſion the oxyd of manganeſe muſt in all probability loſe moſt of its ſuperfluous oxygen, or that which adheres ſo looſely as to be expelled by mere heat, and remains in that ſtate (ſtill very highly oxygenated) in which it is found after having been made to yield oxygen gas in the common way of procuring this gas. This indeed is proved by uſing this calcined oxyd of manganeſe which produces preciſely the ſame colorific effect in the glaſs as the unprepared oxyd.

But if to this purple glaſs ſtill in fuſion in the crucible be added ſome charcoal, tartar, or any carbonaceous matter, or white arſenic, an efferveſcence takes place, the colour gradually

[a] Eſſays. [b] Eſſays on the Analyſis of Iron Ores.

becomes fainter, and at laſt entirely diſappears, leaving the glaſs quite clear and tranſparent.

In the actual manufacture it is found that a very ſmall doſe of manganeſe produces no ſenſible tinge of purple (its natural vitreſcent colour) where there is much of a green tinge to counteract, but if the quantity exceeds this point the purple immediately appears, and this in its turn is corrected by charcoal, or ſimply in the glaſs-houſe, by thruſting a billet of wood down into the melted glaſs, which immediately becomes charred by the intenſe heat, and cauſes the purple hue again to vaniſh with a ſlight effervescence of the glaſs and eſcape of numerous ſmall air-bubbles.

On the other hand if a ſmall quantity of nitre is added to glaſs containing manganeſe the purple colour is immediately reſtored, or, if preſent already, the diſcolouring effect of the charcoal is prevented till the nitre becomes alkalized by the heat, and mixes with the other ingredients of the crucible.

Theſe ſucceſſive changes of colour are alſo ſhewn in a ſtriking manner by means of the blow-pipe. Let a globule of microcoſmic ſalt (compound phoſphat of ſoda and ammonia) be fuſed with the blow-pipe upon a piece of charcoal, and add to it a ſmall portion of the black oxyd of manganeſe, melt them together by the inner blue flame, and the globule will aſſume the violet purple peculiar to this oxyd. Let it be again fuſed and kept melted for a longer time and the colour will again diſappear. Let the globule, now colourleſs, be only ſoftened by the exterior flame of the blow-pipe, and the purple hue will return, but is, as before, again deſtroyed by a longer continuance of the fuſion. The ſmalleſt particle of nitre laid upon the globule alſo immediately reſtores the red colour.

If the globule when colourleſs be now melted in a ſilver ſpoon, an iron plate or any metallic ſupport, inſtead of reſting on the charcoal, the red colour ſpeedily returns, and will not be again removed by any continuance of the fuſion ſo long as it remains on the metallic ſupport.

The above appearances take place with borax inſtead of microcoſmic ſalt, but with a little more tinge of yellow, and not quite the ſame readineſs in aſſuming the different changes.

To explain theſe phenomena a ſuppoſed difference in the ſtate of phlogiſtication has been reſorted to by the former chemiſts, and of oxygenation by thoſe of the preſent day. The oxyd of manganeſe gives the purple colour only ſo long as it remains in its higher ſtate of oxygenation, but when in contact with charcoal, the latter of courſe partially deoxygenates it, carbonic acid gas is formed, the cauſe of the bubbles always obſerved on this occaſion, and the colour is now loſt. Nitre, on the other hand, is known to give out oxygen largely as ſoon as red-hot, and hence the manganeſe immediately retakes from this ſource the oxygen that the charcoal had robbed it of, and reſumes its colouring power. So alſo when on the blow-pipe, the globule at firſt is coloured by the oxyd, but by keeping it entirely involved in the jet of flame, the charcoal on which it reſts is conſumed all around, and after a time the manganeſe loſes oxygen, and with it its colouring power. But on again merely ſoftening it with the outer flame (this latter containing probably little carbonaceous matter which is not actually burning in full activity) a nearly free acceſs of air is allowed to the globule, the charcoal ſupport is not rapidly conſumed, and the colour is reſtored.

The great effect of the burning of the charcoal ſupport is further corroborated by the impoſſibility of deſtroying the colour when fuſed upon any metallic body. Manganeſe therefore when in fuſion appears to have a very weak affinity for juſt that portion of oxygen which makes the difference between the colourleſs and the red glaſs, readily parting with it to carbon of any kind, and alſo to other ſubſtances which will be immediately mentioned, but alſo again attracting it with eaſe from the air, from nitre, and other bodies when giving out oxygen.

The other ſubſtances which take away the colour from glaſs tinged red with manganeſe are all the ſalts with the baſis of ſulphuric acid, ſuch as gypſum, ſulphat of ſoda, &c. and alſo ſulphur itſelf, likewiſe the oxyds of tin and iron and of ſome other metals. Theſe ſubſtances however have only this power when alſo in contact with charcoal, as on the blow-pipe, but not in an earthen crucible, whence it may be preſumed that they are themſelves firſt deoxygenated and the ſulphats brought firſt to the ſtate of ſulphurets, after which they may probably be in a ſtate to abſorb oxygen from the highly oxygenated manganeſe, and render it colourleſs. The metallic oxyds that deprive manganeſe of colour and oxygen are therefore probably *suboxyds*, and in the proceſs become themſelves more fully oxygenated. This agrees ſufficiently well with the primary uſe of manganeſe in counteracting the green colour given to common glaſs by the iron of the ſalts uſed, for the

mon glaſs by the iron of the ſalts uſed, for the circumſtance of its being green makes it probable that the iron is here in the ſtate of ſuboxyd, and by abſorbing oxygen from the manganeſe it prevents this latter when not in exceſs from mixing any of its own red-purple colour, and the iron itſelf, now more highly oxygenated, paſſes to the ſtate in which it gives a *yellow* tinge, which being a lighter colour is much leſs perceptible, and much leſs injures the beauty of the glaſs, This change of iron from green to yellow by the action of oxyd of manganeſe alſo takes place in the liquid ſolution as obſerved by Scheele. On the other hand, manganeſe does not alter the yellow of glaſs tinged by the perfect oxyd of iron except in as far as it mixes its own purple with it.

It muſt be owned however, that it is difficult to account for the decolouring power which arſenic exerciſes over red glaſs tinged by manganeſe on the above ſuppoſition of the oxygenation of the arſenic at the expence of the manganeſe. For it is found that not only the white, and imperfect oxyd of arſenic has this effect, but all the arſeniats, or combinations of the arſenic acid, which is already at the higheſt ſtate of oxygenation, and this alſo occurs in cloſe veſſels; ſo that it is difficult to conceive how, when the arſenic acid is preſent, any oxygen ſhould paſs into it from the manganeſe, or how in any way the latter ſhould loſe oxygen whilſt the glaſs loſes its colour.

The perfect deſtruction of the tinging power of manganeſe by the addition of arſenic in any form is ſhewn as well in the ſimple glaſſes as in thoſe in which any other colouring oxyd is preſent, for when the manganeſe is allowed to be active the colour is a compound of the manganeſe red, and the proper tinge belonging to the other ſubſtance. Thus a mixture of oxyd of cobalt and oxyd of manganeſe, in the colouring ſtate is of a dark purple, but on the addition of any arſeniat, or of white arſenic, the manganeſe is made inactive, and the proper cobalt blue alone appears.

Thus Klaproth [b] made the following experiments on a natural mixed ore of cobalt and manganeſe. Half an ounce of ſilex, and as much calcined borax were combined with 10 grains of a mixed oxyd of cobalt and manganeſe, and vitrified in a porcelain pot. The reſult was a glaſs of a weak cloudy amethyſtine colour.

The ſame mixed oxyd was then diſſolved in muriatic acid, and precipitated by arſeniated ſoda. This gave a lavender-blue powder which was a compound of arſeniated oxyd of cobalt and manganeſe, and being combined with the ſame proportion of ſilex and borax now melted into a glaſs of a very fine ſapphire-blue colour; the manganeſe therefore being made inactive, and the cobalt alone giving the tinge.

Hence the neceſſity where the red colour of manganeſe is wanted to avoid every thing arſenical, and alſo nitre is generally added to keep the manganeſe always at the proper ſtate for imparting its colour.

The oxyd of manganeſe is a very powerful flux for all earthy matters. This is ſeen in the reſult of all the attempts to reduce it to a reguline ſtate in the uſual way of combining with a ſaline carbonaceous flux, and heating in a naked crucible. Not a particle of the oxyd is reduced in this way, but the crucible conſtantly runs down, in a heat ſufficiently intenſe for the reduction of manganeſe, together with all its contents, into a green ſlag. The only way hitherto known of reducing this oxyd is to encloſe it without any ſaline or earthy addition in a crucible lined with charcoal, and apply a very intenſe heat. Manganeſe as well as lead gives a great denſity to glaſs, and alſo like lead it always ſettles ſomewhat to the bottom of the pots where it accumulates, and being here out of the way of moſt of the decolouring additions it gives a purple to the glaſs immediately adhering to the bottom, and partly corrodes the pots, ſo that when theſe are worn out and broken up, they are deeply encruſted with a thick purple vitreſcent ſlag eaſily ſeparable by the hammer.

The white Oxyd of Arſenic is another flux uſed pretty largely in glaſs-making. This ſubſtance (as fully mentioned under the article *arſenic*) is volatile in the fire in proportion as it approaches the metallic ſtate, and hence it is of advantage to employ nitre to oxygenate it more highly, and make it more fixed. Its uſe in correcting the purple red colour of manganeſe has been juſt mentioned. Arſenic is a very powerful flux, and very cheap, but muſt be uſed only in great moderation, for it takes a longer time to mix intimately with glaſs, and to allow it to be perfectly clear, than any other of the additions commonly employed. Glaſſes in which the arſenic is not thoroughly or long enough fuſed have a milky hue, which encreaſes by age: when the arſenic is in exceſs they tend to deliqueſcence, gradually become ſoft, and are decompoſed. They are beſides unſafe as

[b] Eſſays, p. 577.

drinking veſſels. The arſenic is conſtantly volatilizing from the arſenical glaſs when preparing, that is, till it is intimately united with the reſt of the glaſs, after which however it cannot again be ſeparated by heat or any common means.

As arſenic is entirely volatilized when in contact with any carbonaceous matter another uſe has been made of it, which is to diſperſe any ſuch matter which may remain in the glaſs, owing to a defect in the calcination of the alkali, or any other cauſe. [c] When this happens, ſmall lumps of white arſenic are ſometimes thruſt down to the bottom of the glaſs-pots and ſtirred in with the contents, and the arſenic meeting with the unburnt carbon diffuſed through the glaſs unites with it, is ſpeedily volatilized with it, and the glaſs is left freed both from the adhering carbon, and alſo from moſt of the arſenic that was added. The motion excited through the melting glaſs by the volatilization of the arſenic is alſo thought uſeful in haſtening the compleat vitrification of the ingredients.

Nitre is uſed in glaſs-making only in ſmall quantities, and is an acceſſary ingredient to fulfil particular purpoſes. This ſalt at a heat even much below that of the glaſs-pots is readily decompoſed, giving out much oxygen, nitrous gas and azot, and leaving behind its pure potaſh. It is of ſervice in deſtroying any carbonaceous matter in the ingredients of the glaſs (with which it ſhould be mixed before fuſion) and its uſe in fixing arſenic, and in keeping up the tinging power of manganeſe has been already mentioned. The ſame circumſtance of keeping metallic oxyds up to their higheſt ſtate of oxygenation, alſo renders this ſalt often uſeful, and even neceſſary in the preparation of ſome others of the coloured glaſſes.

Of the proportion of Silex to the Saline fluxes.

The exact proportion and number of ingredients that enter into every ſpecies of glaſs cannot eaſily be obtained with any certainty, though many apparently good mixtures are given by different authors which will be afterwards mentioned. But ſome obſervations may be made on the ſolvent power of mere alkali over ſiliceous earth, which is the baſis of the rules for the compoſition of glaſs, as, ſtrictly ſpeaking, nothing elſe is neceſſary for the formation of glaſs than a ſolution of ſilex in alkali by a melting heat, and all the other additions are more properly uſeful than neceſſary ingredients.

When ſilex is melted with twice its weight, or more, of dry carbonated alkali, either potaſh or ſoda, the reſult is a very ſoft deliqueſcent vitreous maſs, always more or leſs opake, ſtrongly alkaline to the taſte, and which on expoſure to moiſt air, or more ſpeedily if put into water, totally diſſolves into a clear liquor which is a ſolution of ſilex in alkali. This ſilicited alkaline ſolution is decompoſed by all the acids, which ſeparate the ſilex in the form of a white powder.

When the alkali employed (meaning all along in this place the dry carbonated alkali) only equals the ſilex in weight, or at leaſt does not much exceed it, the glaſs is now tranſparent, but is ſtill ſoluble in water as before.

It is not till the alkali is diminiſhed to about one half of the weight of the ſilex that the glaſs becomes perfectly hard and inſoluble in any corroſive liquors, (the fluoric acid excepted) and in ſhort, acquires the character of a perfect glaſs.

This proportion therefore, that is, two parts of ſand to one of alkali is uſually the datum on which the doſes of the ſpecies of alkalies actually uſed are regulated. [d] Thus if common wood aſhes (of which the alkaline part is reckoned at no more than 10 per cent.) are employed, 100 lbs. of theſe would require no more than about 20 lb. of ſand. If the beſt Spaniſh barilla containing from 45 to 50 per cent. of carbonat of ſoda, be uſed, an equal weight of ſand may be added; but if purified pearlaſh be taken, it will melt down perfectly twice its own weight of ſand.

But glaſſes compoſed merely of pure alkali and ſand require a very ſtrong fire for their fuſion, and are hard, harſh, and difficult to work. They are therefore never uſed alone, for even when common aſhes and ſand are the only ingredients, the aſhes contain an abundance of earth and other ſubſtances. As one half the weight of the ſand is reckoned an abundant allowance of alkali, it follows of courſe that when litharge, arſenic, borax, or any other fluxes are employed, the quantity of alkali will be proportionally diminiſhed.

It muſt not be ſuppoſed that the glaſſes themſelves contain nearly the original proportion of ſilex and alkali that was put into the glaſs-pots. Of theſe two materials the alkali is abundantly volatile in the intenſe fire neceſſary for glaſs-making, but the ſilex is abſolutely fixed, and hence in proportion to the ſtrength and continuance of the fire the relative

[c] Loyſel, Art. de la Verrerie.

[d] Encyclop. Arts & Metiers. Article Verre.

quantities of the two are conſtantly altering, that of the alkali diminiſhing, and that of the ſilex and other ingredients increaſing. That the alkali does really volatilize, and very rapidly at firſt when in large proportion in the mixture, is put beyond a doubt by the denſe vapour which always proceeds from the glaſs-pots when the glaſs is firſt heating, and which corrodes the covers of the crucibles, and by various other teſts is proved to be part of the alkali eſcaping. This may partly be owing to a want of thorough mixture of the ſilex, which, though in grains when ſand is uſed, is very far ſhort of intimate mechanical mixture. No continuance of heat indeed can drive off all the alkali, for when once melted into glaſs, it muſt remain as ſuch, but the ſolvent power of alkali upon ſilex increaſes in proportion as the temperature is raiſed, as occurs in moſt other caſes of ſolution.

Mr. Loyſel [c] has the following remarks on the ſubject of the volatilization of the alkali, but it is to be wiſhed that he had given more of the particulars of the experiments on which they are founded. If a mixture of two parts of ſand and one of alkali be expoſed for the accuſtomed number of hours in the ordinary glaſs-houſe fires (about 8000° degrees Reaumur) the glaſs when finiſhed will contain no more than a fourth part of alkali, all the reſt having been diſſipated. If the glaſs be heated ſo as to retain no more than about 15 or 20 of alkali to 100 of ſilex, it will be very hard, tranſparent, and almoſt equal in beauty to rock cryſtal. Of a glaſs originally made of two parts of ſand and three of alkali, Mr. Loyſel obſerves that if kept in the heat of 3000° for one or two days the reſult will be a ſoft glaſs retaining nearly equal parts of alkali and ſilex; if further heated to 9000° a ſolid glaſs will remain compoſed of about four parts of ſilex to one of alkali; and laſtly, if urged to a heat of 10 to 12000° the glaſs will be extremely hard, brilliant, and will conſiſt of no more than three parts of alkali to ſeven of ſilex.

All the common alkalies are largely mixed with various neutral ſalts, particularly common ſalt, and ſome of the ſulphats. It does not ſeem entirely aſcertained what ſhare theſe have in the vitrification. It is generally aſſerted that they are merely inefficient and act as extraneous bodies, and it is certain that during the fuſion of the glaſs materials a quantity of ſcum riſes to the top of the pots, which is a very heterogeneous mixture of common ſalt and other neutral ſalts and other impurities of the alkali, as will be preſently noticed. Common ſalt being readily volatile in a full red heat can ſcarcely be ſuppoſed to contract much permanent union with the ſilex, and yet if a quantity of this ſalt be incloſed in a well luted crucible and heated without addition, it will readily penetrate the ſides of the veſſel, and deeply corrode them in its paſſage.

But the ſulphats being fixed in the fire can withſtand without volatilization all the heat of the glaſs-pots, and at this temperature they are decompoſed largely by the ſilex, this earth uniting with the alkali of the ſulphat and the acid flying off alone. Thus if three parts of ſulphat of ſoda and one of ſilex are put into an earthen retort with a receiver, and the fire ſtrongly urged to whiteneſs, a tranſparent glaſs of ſilex and ſoda will remain, and the receiver will contain much ſulphureous acid.

This is one of the very frequent examples of chemical affinity being changed by temperature, for at any common heat the ſulphuric acid has a much ſtronger affinity for alkali than this has for ſilex, and therefore will decompoſe the ſolution of ſilicited alkali, and ſeparate the ſilex. Of the common neutral ſalts therefore, the muriats probably add but little to the quantity of real flux, but on the contrary, the ſulphats are important additions, and leave in the glaſs pot the alkali or earth with which they were united. Hence in ſome places ſulphat of ſoda where impure and not referved for other purpoſes, is ſold to the glaſs-makers, and found to anſwer compleatly. This is the caſe at Freyberg, where the pyritical ores of ſilver and copper after roaſting are converted into ſulphats, from which a large quantity of impure ſulphat of ſoda mixed with ſome arſeniats is obtained, which is uſed without preparation as the ſole flux in glaſs-making. [f]

Of the Glaſs Furnaces and Pots.

Glaſs is made in large deep pots or crucibles cloſed every where except at one ſide-opening, and arranged round a kiln or dome-ſhaped oven, into the middle of which they project, and by which they are entirely encloſed except at the ſide orifice above mentioned, which opens into a ſmall receſs formed by the alternate projections of the maſonry and flues of the kiln in which receſs the workmen ſtand.

The kiln is ſupported on arches, beneath which is a large ſpace for a briſk and copious draught of cold air from without. The floor of the kiln nearly level with the ground is

[c] Art. de la Verrerie.

[f] Journ. de Phyſ. tom. 51.

covered with a grate of very ſtrong iron bars on which the fuel is thrown, and the flame draws very ſtrong and fierce round the pots, and paſſes out together with the ſmoke, in one body through the top of the dome which is lengthened into a chimney for the ſpace of a few feet. The preciſe conſtruction of the glaſs-houſe can only be underſtood by figures, which cannot be given in this place. At the top of the dome between the pots and the chimney, is a kind of broad covered ſhelf which is heated by the flame in its paſſage round it, but to a much leſs degree of intenſity than the pots, and ſerves as a receptacle for the glaſs as ſoon as wrought, in which it may cool ſlowly and gradually. This is the *annealing oven*.

Very great care is required in building a glaſs-houſe to form the bricks of an earth which combines in the higheſt degree the qualities of denſity and infuſibility, ſo as to enable them to withſtand the unceaſing action of very ſtrong heat for a great length of time, for the fires are ſeldom ſuffered to go out from the time the furnace begins to be in action, till the inevitable wear and fuſion of the walls renders a repair neceſſary, which may be in about two or three years. But ſtill greater attention is required in ſelecting proper materials for the glaſs-pots, as theſe have to withſtand for a given time not only the conſtant action of a very fierce fire, but alſo the ſolvent power of the glaſs itſelf with the variety of powerful fluxes in full vitrification. The pots therefore, being made of earth, muſt neceſſarily be themſelves always gradually diſſolving in their contents, and hence, beſides the property of difficult fuſibility, an earth of conſiderable purity is required for theſe, ſo that a ſmall admixture with the glaſs may not injure its quality.

The chief material both of the walls of the furnace and of the pots is clay, as it is of almoſt every veſſel and ſubſtance deſtined to bear a long and violent heat. This is mixed with ſand, in different proportions according to its quality, for the fire-bricks and other parts of the furnace. On an average a fine ſtiff clay will require about two-thirds as much of ſand to bring it to ſuch a conſiſtence that it will work eaſily, dry into a very compact maſs, and reſiſt the impreſſion of fire for a length of time. Still however, this addition of ſand renders it in ſome degree fuſible, ſo that when the fire is in activity, drops of vitrified earth are conſtantly and ſlowly falling from the walls, ſome of which cannot be prevented from dropping into the glaſs and mixing with it. The crucibles are made of a ſtill more refractory mixture, which conſiſts ſimply of raw and of burnt clay, the latter is called technically *cement*, and is procured from the remains of the former furnaces when pulled down for reparation. As clay loſes its plaſticity by baking, it then anſwers all the purpoſes of ſand in diminiſhing the tenacity of the maſs, and eſpecially in leſſening the ſhrinkage whilſt drying, and being the ſame kind of earth as the unbaked, it adds nothing to the vitreſcibility of the material, for as has been already ſhewn, earthy compounds are, *ceteris paribus*, fuſible in proportion to the number of ingredients of which they are compoſed.

The particular manipulations employed in conſtructing a glaſs-furnace and pots are foreign to the preſent purpoſe: very great precaution is uſed in drying them thoroughly and very gradually. This is peculiarly neceſſary in making the pots, for as they are intended to hold a conſiderable weight of glaſs, and to laſt many months, they muſt be made very thick and ſtrong, and therefore would readily crack without much care. When finiſhed they are firſt kept in a warm ſheltered room for many weeks to diſſipate much of their moiſture, and the ſmall fiſſures formed by the unequal ſhrinking of the clay are cloſed up by beating gently with a mallet. They are afterwards heated extremely gradually in a ſmall oven made for this purpoſe, and are ſlowly brought to a red heat and kept there the requiſite time, after which they are removed, whilſt ſtill hot, to the furnace and ſoldered down to their place by fire clay. A ſtill further ſhrinkage takes place when in the furnace, for which reaſon they are let to ſtand empty for a day or two before they are fitted to receive the materials for glaſs. Theſe pots laſt on an average about a year, and hence they muſt be changed once or twice during the continuance of the furnace itſelf.

The fuel uſed in this country is conſtantly coal, and the beſt is of the kind that gives a ſtrong ſteady blaze. As the glaſs-pots open only outward none of the fuel or flame comes in contact with their contents, except through any accidental crack in the clay ſoldering.

Conſiderable variety prevails reſpecting the exact form and conſtruction of the furnace and crucibles, in different countries, and alſo according to the kind of manufacture, and in particular the plate-glaſs furnace requires a different arrangement.

Of the Fuſion and working of Glaſs.

The ſand, alkali, and other materials for the

glaſs after mixture are uſually firſt calcined for a longer or ſhorter time by a ſeparate operation before they are transferred to the glaſs-pots. This operation is called *fritting*, and is performed either in ſmall furnaces cloſe adjoining to the proper glaſs furnace and heated by the ſame fuel after the chief force has been ſpent upon the glaſs-pots, or elſe in ſmall furnaces or ovens conſtructed for the expreſs purpoſe. The uſes of fritting are, to drive off all moiſture from the materials which might endanger the glaſs-pots, to expell part of the carbonic acid from the alkalies and chalk, and thus to moderate the ſwelling up in the glaſs-pots, and eſpecially to cauſe an adheſion or commencement of chemical union between the alkali and ſilex, and the metallic oxyds. For if the raw materials were immediately expoſed to the intenſe heat of the glaſs-pots, the alkali would flow thin like water, and the groſſer particles of the ſand and the heavier oxyds would fall to the bottom, leaving the alkali above nearly diſengaged, and therefore liable ſtrongly to act on the crucibles, and alſo a large portion would be rapidly volatilized to mere waſte. The glaſs materials therefore would thus have an exceſs of ſand from the loſs of the alkali, and a portion would remain at the bottom unvitrified.

Fritting ſhould be gradual, and carried to the point of ſemi-vitrification, in which the materials ſtrongly adhere and begin to become paſty, but are ſtill opake and not yet homogeneous. It has the further uſe of deſtroying any carbonaceous matter.

When the materials are ſufficiently fritted they are thrown into the glaſs-pots with clean iron ſhovels through the ſide opening. The fire is previouſly raiſed to its greateſt intenſity to prevent the whole furnace from being chilled and to ſave time. As the fritted materials are much more bulky than when they fall into a thin-flowing glaſs, the pots receive their full charge by two or three ſucceſſive portions, the laſt-added being always thoroughly melted down before a freſh charge is thrown in. When full, the ſide opening is cloſed up with wet clay, except a ſmall hole for examining the work, which cloſure is pulled down when the glaſs is well refined and about to be worked off.

As ſoon as the frit begins to feel the action of the fire in the glaſs-pots which is immediately raiſed to its greateſt pitch, it ſinks down into a ſoft paſty ſtate, which gradually encreaſes in tenacity till a perfect fuſion is effected. It is ſtill however opake at firſt, owing to the riſing of a quantity of a white porous ſcum, the nature of which has engaged much attention, and is known by the name of *ſandiver*, or *glaſs-gall*. This ſubſtance appears to be a confuſed maſs, conſiſting of all thoſe ſalts contained in common alkalies which readily melt at ſomewhat leſs than a glaſs-making heat, and are either naturally conſiderably volatile, or have little if any affinity for ſilex, and do not unite in the compoſition of glaſs, but being ſuperficially lighter, riſe to the top. There is another heterogenous ſubſtance alſo called ſandiver, which ſometimes is found at the bottom of the pots, and is taken out when the whole is worked off. The nature of this is very different from the other, and conſiſts apparently of a vitrified maſs of arſenic and earthy impurities. But the ſcum or proper *glaſs-gall* is almoſt entirely ſaline. When laded out and cooled it forms a white crumbly maſs, ſometimes quite white, and at other times brown and fouled, and ſtrongly ſaline, but not very uniform in its compoſition, being ſometimes merely ſalt, often very bitter, probably as common ſalt or ſulphat of potaſh predominate. Glaſs-gall is very volatile in a ſtrong fire, ſo that it is conſtantly diſperſing from off the ſurface of the glaſs in a denſe vapour, at firſt thick and black, afterwards whiter, which very powerfully corrodes the top of the crucible in its paſſage. If the fuſion were continued long enough the whole would be diſperſed merely in this way, but it is generally ſcummed off with iron ladles, and ſold to metal-refiners as a powerful flux. As part of the alkali itſelf certainly is diſſipated by the continuance of fire, partly before it can unite with the ſilex, partly from the glaſs itſelf, much of the corroſion of the pots muſt be owing to this circumſtance, and probably it muſt alſo unite in part with the glaſs-gall, which renders it ſlightly deliqueſcent. An abundance of this glaſs-gall is one of the greateſt inconveniences that the glaſs-maker can meet with, for it requires a conſiderable time of very ſtrong heat before the whole can be diſſipated, or if the glaſs be wrought before it is thoroughly purged of this material it is full of bubbles, unſound, and has a cloudy gelatinous appearance. Glaſs made with potaſh is more likely to ſuffer from glaſs-gall than the ſoda glaſſes, for the potaſh-glaſſes are harder and do not run ſo thin as the others, and the glaſs-gall ariſing from them does not ſo eaſily diſſipate in the fire.

During this part of the proceſs ſmall ſamples

are occaſionally drawn out of the pots with an iron rod to examine the ſtate of the materials, and gradually the glaſs becomes more and more flexible, denſe, and leſs brittle, and at laſt the glaſs-gall is entirely diſſipated, and the vapours which it occaſioned are no longer to be perceived. This is the firſt and very well defined ſtep in the proceſs of glaſs-melting.

The glaſs is now full of minute ſpecks or bubbles which the continuance of the heat cauſes to expand and burſt at the top, till at laſt it reſines beautifully clear, tranſparent, and colourleſs, as is ſeen by the ſamples which are from time to time taken out and cooled. This ſecond proceſs, namely, from the ceſſation of the vapour of the glaſs-gall and its thorough removal, to the time when the glaſs is perfectly clear and free from bubbles, is called the *refining*. The glaſs is now compleat, but is of too thin a conſiſtence to be wrought, it is therefore cooled by ſtopping the draught of the fire round the individual pot, and in cooling it thickens to the working point. The clay with which the opening was luted is then picked off and the working begun. But if the glaſs is to be caſt into plates (as all the large mirrors are) a much ſhorter cooling is required, as for this purpoſe it is required to flow very thin and hot.

The particular manner of managing the pots, and the alternations of filling and working them off varies conſiderably, and depends chiefly on the convenience of the manufacturer. Sometimes half the number of pots (which are generally ſix in common glaſs-houſes) are kept in the working ſtate, whilſt the materials are melting or refining in the three others, and ſometimes they are all filled together. On an average it takes about forty-eight hours for the fine flint glaſſes, from the time that the pots are firſt filled till the glaſs is ready for working, but there is no occaſion to uſe it immediately, as it may be allowed to remain a conſiderable time at a low working heat without any injury.

When the glaſs is cooled down to the working heat, which is a very full red, it has a kind of conſiſtence and tenacity not exactly to be found in any other ſubſtance in nature. It is juſt ſoft enough to yield with the greateſt eaſe to any outer impreſſion, even to the force of the breath when urged pretty ſtrongly in the center of the glowing maſs, and may be bent, pulled out and ſhaped in every poſſible way; and its tenacity is ſuch that it extends uniformly without producing any cracks or fiſſures, but when ſtretched to the utmoſt it pulls out to a ſolid ſtring, the diameter of which is conſtantly decreaſing till it ſeparates from the maſs in a thin capillary thread. As it cools it ſtiffens, and becomes perfectly brittle, which takes place when no longer red hot, and at this time alſo it becomes tranſparent. Melted glaſs adheres very feebly to poliſhed metal, ſo that it is wrought with bright iron tools with the utmoſt eaſe.

Almoſt every kind of glaſs veſſel, and utenſil, common window glaſs, and in ſhort, almoſt every manufactured glaſs article except plate-glaſs, is ſhaped out of a hollow globe formed by blowing. The inſtrument uſed for this purpoſe is ſimply a hollow iron rod about four or five feet long, which the workman firſt dips in the glaſs-pot and turns about till a ſufficient maſs of the melted glaſs adheres to it, he then holds it near the ground by which the maſs pulls out and lengthens by its own weight, and then blows ſtrongly through the tube. The breath thus penetrates the center of the red-hot maſs, and immediately extends it into an uniform hollow globe of the required thickneſs. This muſt be immediately blown out as large as intended, and the force of the breath kept upon it for a few ſeconds till it ſtiffens by cooling, otherwiſe it would again ſink in by the compreſſion of the denſer external air. This operation produces a hollow globe, adhering by a neck to the iron rod, and is the original form out of which the others are faſhioned.

It would be impoſſible to give in a ſhort ſpace an adequate idea of the eaſe and ſimple dexterity by which, with a few inſtruments, this moſt beautiful ſubſtance is ſtretched out, enlarged, cloſed, perforated, and formed by a few ingenious manœuvres into all the common utenſils. As a ſingle and ſhort example, the making of a common tumbler may be given. A hollow globe with a ſhort neck being firſt blown on the iron rod as above mentioned, it is taken off it the following way: an aſſiſtant dips the end of a ſhort ſolid iron rod into the glaſs-pot, and brings it out with a little of the melted glaſs adhering, this is immediately thruſt againſt the bottom of the globe at the part directly oppoſite the neck, to which it firmly unites, ſo that the globe becomes cemented upon this ſecond rod by means of the melted glaſs. The workman then wets a ſmall piece of iron with his mouth and lays it on the neck of the globe which is ſtill extremely hot, and this cracks it quite round in a ſecond or two, ſo that

with a ſlight pull it comes off and detaches the hollow rod, leaving the globe now open at the neck, and transferred to the ſecond rod at the oppoſite ſide. The globe being now open is again ſoftened by holding it a few ſeconds over the mouth of the glaſs-pot, and is cut away from the open end to the form of a cup by iron ſhears. The workman when faſhioning the globe uſually ſits upon a kind of arm chair, the arms of which ſlope forwards, and are covered with a flat ſmooth iron plate, and by laying the iron rod ſtraight before him, reſting on both the arms of his ſeat, and twirling it backwards and forwards, the hot glaſs at the end is made to revolve like clay on a potter's lathe, and thus is opened, widened, or compreſſed at pleaſure by any ſimple iron inſtrument that is preſſed againſt it. The globular cup is thus extended eaſily into a cylinder, or made barrel-ſhaped, if this be the required form, and is ſmoothed up at the edges. It only now requires to be ſeparated from the iron rod, which is done as before, ſimply by wetting it at the point of attachment, and the tumbler drops off compleat. This laſt operation leaves that burr or roughneſs with ſharp fragments which is ſeen at the bottom of all glaſs veſſels unleſs taken off by grinding.

Another important proceſs is required before the glaſs veſſel is fit for uſe, which is that of *annealing* or cooling very gradually. All glaſs articles require annealing except thoſe that are very thin and uniform without joining or burr of any kind. Without this precaution the glaſs remains always liable to fly by the leaſt change of heat and cold, by the ſmalleſt ſcratch, or even apparently without any external cauſe. The preciſe mechanical cauſe of this diſpoſition to crack in unannealed glaſs is very difficult to explain, but generally ſpeaking it is ſuppoſed to be the forcible contraction of the outer part by ſudden cooling, whilſt the inner portion is ſtill ſoft and half-fluid, ſo that the whole fixes with a permanent ſtrain or inequality of preſſure of one part upon the other; and as glaſs is extremely elaſtic, though brittle, any force which tears aſunder a portion, however ſmall, of the tenſe part, communicates a ſtrong and ſudden impulſe over the whole maſs. The annealing is generally performed in a hot chamber built for the purpoſe at the top of the glaſs-houſe above the crucibles and a little below the chimney as already mentioned. The heat is here ſo moderate as not to ſoften the glaſs, and the articles are gradually withdrawn to a cooler part till they are cold enough to be taken out for uſe. Common articles are generally annealed in the courſe of a day. The place of all others in which ill-annealed glaſs is moſt liable to break is at any point of junction where two pieces are cemented together when hot, and as different kinds of glaſs contract to a different extent, two diſſimilar pieces of glaſs ſhould not be joined together.

The hard glaſſes, and thoſe in particular made only with alkali and earths require much more annealing than the ſofter and more fuſible glaſſes into which litharge enters largely.

The extraordinary fragility of unannealed glaſs is ſhewn in a very ſtriking manner by two kinds of experimental toys made for the purpoſe, the one is the *Bologna phial*, as it is uſually called, and the other the *Rupert's drop*. The Bologna phial is ſimply a phial of any form whatever, made of any kind of glaſs, but much thicker at bottom than at top, and cooled immediately without annealing. Theſe being pretty ſtout from their thickneſs will bear a ſmart blow with a wooden mallet or any blunt inſtrument, or the concuſſion of a leaden bullet dropped into it from a conſiderable height, without injury; but if any ſharp body however ſmall, ſuch as a large grain of ſand, or better a ſhiver of a gun-flint be dropped in from only a few inches height, the bottom cracks all round juſt above the thickeſt part and drops off. The ſame effect happens if the bottom be ſlightly ſcratched with any hard body. When very brittle, if a hard angular ſubſtance ſuch as a cut diamond be dropped in, it ſometimes will paſs through the bottom, though very thick, with apparently as little reſiſtance as through a ſpider's web. Theſe glaſſes when they have received the firſt injury do not always crack immediately, but remain whole ſometimes a few minutes, ſometimes for hours, and then ſuddenly give way.

The Rupert's drop is ſimply a ſmall ſolid lump of green bottle glaſs poured when red-hot into water, and therefore is a rounded lump gradually extended into a kind of tail nearly capillary at the extremity. This ſolid lump will bear very conſiderable violence on the rounded end without injury, and is altogether extremely tough, but when the leaſt portion of the thin end is broken off, the whole burſts with a ſmart ſnap, inſtantly crumbles into a countleſs number of fragments as ſmall as fine ſand, which from their very minuteneſs do no other injury to the hand holding it, than a ſlight ſtinging from the ſudden concuſſion.

This moſt ſingular phenomenon is obviouſly

owing to ſome permanent and very ſtrong inequality of preſſure, for when they are heated ſo red as to be ſoft and merely let to cool of themſelves, this property of burſting is entirely loſt, and at the ſame time the ſpecific gravity of the drop is encreaſed. [g]

The peculiar brittleneſs of the Bologna phial is alſo removed by again heating and cooling ſlowly.

A defect in the annealing of common window glaſs is alſo ſhewn when cut by the diamond. When the glaſs is well annealed the diamond cuts it with moderate eaſe, making an uniform ſmooth furrow, at firſt dark, but which gradually opens and then appears as a bright ſilver thread; but when the glaſs is badly annealed, the diamond works with much more difficulty, the cut opens very ſlowly, and often flies into a different direction, or the glaſs entirely breaks.

The other more common defects of glaſs are a liability to be acted on by corroſive liquors (which takes place when too much ſaline flux has been uſed) and alſo a number of viſible imperfections, ſome of which materially injure the ſoundneſs as well as beauty of the manufactured articles. The chief of theſe viſible defects are *ſtriæ* [h], *threads*, *tears*, and *knots*. The *Striæ* are undulating waves in the glaſs, perfectly tranſparent and vitrified, but which produce much ſtrange diſtortion when uſed for windows or for optical purpoſes. This defect ariſes from the imperfect mixture of the materials, and the great difference in their ſpecific gravities. For the gravity of glaſs made ſimply with alkali and ſand is about 2.3 or 2.4, that of alkali and crucible clay, about 2.5; that of alkali and chalk 2.7 or 2.8; whilſt the vitrified oxyd of manganeſe alone weighs 3.2 and the glaſs of lead 7.2 nearly. Therefore when theſe are all together melted in the glaſs-pot, if they are not thoroughly mixed, they are in the caſe of liquors of unequal denſity in contact with each other and ſlightly agitated ſo as to ſhake the different materials into ſtreaks or waves.

The defect from this cauſe is ſeen very ſtrikingly in ordinary priſms, or pieces of ſolid glaſs of a certain thickneſs, which are ſeldom quite uniform in denſity throughout. For very nice purpoſes it is often of uſe when ſmall moveable crucibles are uſed, to invert them when the glaſs is melted and empty the contents, whereby the heavier parts become mixed with the lighter as they fall through them.

Threads in glaſs-making are thoſe ſtreaky filaments which ariſe from the vitrification of the clay. They are generally green and often render the glaſs more liable to crack at theſe parts.

Another and one of the worſt defects is *Tears*, or drops of vitrified clay falling down from the furnace into the pots and entangled with the glaſs. Articles made of glaſs with this defect are always very brittle, and generally break of themſelves by ſlight changes of heat and cold. This is the more likely to happen in proportion as the tear is nearer the ſurface.

Glaſs when not ſufficiently refined by continuance of the melting heat is always full of ſmall bubbles. This fault may alſo happen from a deficiency of flux which renders the glaſs leſs fuſible, and therefore ſtiffer during the ordinary time and degree of heating ſo that the bubbles cannot eaſily diſengage themſelves. Hence the ſoft fuſible glaſſes with much lead are much leſs liable to this fault than the hard green bottle glaſs which is made only of alkali and earth.

Another defect is *knots* which ariſe either from a portion of ſand that has eſcaped vitrification and remains entangled in the glaſs, or from a remaining quantity of glaſs-gall; or from bits of the crucible which may be accidentally knocked off by the iron inſtruments uſed in the working.

Of the different kinds of Glaſs.

Though an infinite variety is found in the quality and compoſition of different glaſſes, there are ſome principal kinds made for totally diſtinct purpoſes which may be ſhortly noticed.

The *flint glaſs* of London and other parts of England (called by foreigners *cryſtal*) is that beautiful, ſoft, brilliant, fine glaſs of which both the common and fineſt articles of white glaſs in domeſtic or ornamental uſe are manufactured. Many optical inſtruments are alſo made of the ſame material. It is particularly diſtinguiſhed for the quantity of litharge which enters into its compoſition, on which account it is by far the heavieſt, the moſt brilliant, the ſofteſt, and the eaſieſt to work, and alſo the moſt expenſive.

The preciſe proportions of ingredients are not uſually known, but the following is ſaid to make an article of the beſt quality, namely; 120 parts of fine clean white ſand, 40 of pearl-aſh well purified, 35 of litharge or elſe minium, 13 of nitre, and a ſmall quantity of black oxyd of manganeſe. The diſtinct uſe of theſe in-

[g] Own Exper.

[h] Loyſel.

gredients has been already explained. Very different proportions will alſo produce a fine glaſs of ſimilar quality, and in particular the quantity of lead may be much encreaſed which naturally gives a yellow tinge but which the manganeſe counteracts. The following compoſition for a fine cryſtal glaſs is given by Loyſel: 100 pounds of white ſand, 80 to 85 of red oxyd of lead, 35 to 40 of pearlaſh, 2 to 3 of nitre; and one ounce of manganeſe. The ſpecific gravity of this glaſs and of the common London flint glaſs is about 3.2.

The oxyd of lead is ſo abundant in this glaſs that it may be partially reduced in a very curious manner. If a tube of it be made red-hot and hydrogen gas paſſed through, the whole inner ſurface becomes covered with a half-brilliant black coating owing to the reduced lead, and moiſture appears at the further end. This was diſcovered by Dr. Prieſtley.

Crown-glaſs is the name given to the beſt ſort of window glaſs, the compoſition of which varies conſiderably, but it differs eſſentially from the laſt in containing no lead nor any metallic oxyd except manganeſe and ſometimes oxyd of cobalt in minute doſes, for the ſole purpoſe of correcting the natural colour and not as a flux. This kind of glaſs therefore is much harder and harſher to the touch than the flint glaſs, but when well made is a very beautiful and perfect article. The compoſition is ſand, alkali, either potaſh or ſoda, the vegetable aſhes that contain the alkali, and generally a ſmall portion of lime. A ſmall doſe of arſenic is often added to facilitate the fuſion. Zaffre or the oxyd of cobalt with ground flint is often uſed to correct the dingy yellow which the inferior kind of crown-glaſs naturally acquires, and by adding the blue, natural to glaſs coloured with this oxyd, to convert the whole into a ſoft light green. The green hue thus given is very ſlight and not diſagreeable to the eye, and is hardly perceived unleſs the light paſs through a great thickneſs of glaſs, as happens when a piece is held up edgeways. The quantity of zaffre neceſſary for this effect is extremely ſmall, one ounce being ſufficient for 1000 lbs. ſo that it is only $\frac{1}{16000}$ of the whole. It need hardly be added that when the ſand, alkali, and lime, are very fine, and only theſe ingredients are uſed, no zaffre or corrective of bad colour is required. A great quantity of fragments and refuſe pieces of glaſs is always collected during the working, and theſe are added again to the next fuſion, but as glaſs always loſes alkali by the long continuance of fire and becomes thereby harſher and leſs fuſible, too great a portion of theſe refuſe bits (which of courſe undergo twice as long a fuſion as the raw materials) will very ſenſibly alter the quality of the glaſs. As however they conſiſt of glaſs already refined, the pot which contains much of them is much ſooner brought to a working ſtate, as it contains leſs glaſs-gall and impurities. Theſe fragments of glaſs are reduced to groſs powder by being heated red-hot, and immediately plunged into cold water, which ſplits them in every direction and enables them to be readily broken down. They ſhould not conſtitute much more than a third of the whole compoſition. A very fine glaſs of this kind may be made by 200 parts of pretty good ſoda, 300 of fine ſand, 33 of lime, and from 250 to 300 of the ground fragments of glaſs. [i]

The manufacture of the common window glaſs though made by blowing, is carried on in a conſiderably different manner from that of the common flint-glaſs articles, as the object is to produce a large flat very thin plate of glaſs, which is afterwards cut by the glaziers' diamond into the requiſite ſhape. The ſteps of the proceſs could not be underſtood by mere deſcription, but it may juſt be mentioned that the workman firſt takes a very large maſs of glaſs on the hollow iron rod, and by rolling it on an iron plate and ſwinging it backwards and forwards cauſes it to lengthen by its own weight into a cylinder, which is then made hollow by blowing with a force of breath which only thoſe that are uſed to the buſineſs can command, and is brought out to the requiſite thinneſs. The hollow cylinder is then opened by holding it to the fire, which by expanding the air confined within it (the hole of the iron rod being ſtopped) burſts it at the weakeſt part, and when ſtill ſoft it is ripped up through its whole length by iron ſhears, opened out into a flat plate and finiſhed by annealing as uſual.

Common green bottle glaſs is another kind, which indeed is by no means uniform in its compoſition, but is made almoſt entirely of ſand, lime, and ſometimes clay, alkaline aſhes of any kind according as cheapneſs or convenience direct, and more eſpecially of kelp in this country, of barilla, varec and the other varieties of ſoda in France, and of wood-aſhes in many parts of Germany, and the like. To this too is ſometimes added even the earth remaining from ſaline aſhes, after the alkali and ſalts

[i] Encyclo. Method.

have been extracted by lixiviation, and in England flags from the iron furnaces. This refuſe matter is ſtill a flux of ſome power when in mixture with other earths, and it ſtill retains a ſmall quantity of ſalts which are not totally extracted. Bottle glaſs is a very hard well-vitrified glaſs, not very heavy relatively to its bulk and being fuſed at a very high heat, and from the impurity of the alkali and the abundance of earthy flux containing but a ſmall proportion of real ſaline matter, it reſiſts the corroſive action of all liquids much better than flint-glaſs. Beſides being uſed for wine-bottles it is much employed for very large retorts, ſubliming veſſels, and other proceſſes of chemical manufacture, and here too it has the additional advantage of bearing as much as a pretty full red heat without melting or ſinking down into a ſhapeleſs lump as the lead glaſſes would do. The following compoſition is given by Loyſel as a good and cheap material for bottle glaſs, 100 parts of common ſand, 30 of varec (a kind of coarſe kelp made on the weſtern coaſts of France) 160 of the lixiviated earth of aſhes, 30 of freſh wood-aſh or any other kind of aſh, 80 of brick-clay, and any quantity, generally about 100, of broken glaſs. This compoſition gives no glaſs-gall.

A good bottle glaſs but nearly black and opake has been made in France of another material which probably may be applied in many countries advantageouſly: it is the decompoſed pulverulent baſaltic earth found in the vallies of all baſaltic countries. In France it abounds in the Vivarais, in Languedoc and Auvergne. The firſt glaſs of this kind appears to have been made in 1780 by a M. Ducros at the ſuggeſtion of Chaptal [k] who ſimply melted ſome of this baſalt without addition in a glaſs-pot, and formed of it two very light, black, or rather deep yellow, ſhining, perfect bottles. In ſubſequent trials by another artiſt a mixture of equal parts of baſalt and ſand was employed, as being preferable to the baſalt alone, and for a while there was a very conſiderable demand for bottles of this material, but the manufacture was abandoned owing to the want of uniformity in the ingredients, which made them often fail. The glaſs produced hereby was of a green olive.

It may not be unintereſting alſo to give the reſults of ſome experiments of M. Alliot on different mixtures of this baſaltic earth. Seven crucibles filled with different mixtures were heated for eighteen hours in a common potter's furnace (a glaſs-houſe not being at command, which however gives a leſs intenſe heat than the glaſs furnaces, and therefore if uſed in manufacture a greater effect might be allowed than was here noticed. The reſults were the following.

No. 1. contained the pure baſaltic earth, and melted into a black, opake glaſs, moderately well melted.

No. 2. was a mixture of $\frac{1}{3}$ baſalt, $\frac{1}{3}$ of aſhes, and $\frac{1}{3}$ of white quartz in powder. It was a milky, brilliant, coffee-coloured glaſs reſembling fine porcelain.

No. 3. was a mixture, in equal parts, of baſalt and common ſand. It was moderately well melted, of a blackiſh-blue in maſs, but in thin laminæ was of a yellow-green.

No. 4. was a mixture, in equal parts, of aſhes and a volcanic granite. It melted well, gave a very fine dark yellow glaſs, of great luſtre, and would have been very proper for bottles.

No. 5. contained $\frac{1}{19}$ of ordinary ſoda, $\frac{6}{19}$ of common ſand, and $\frac{12}{19}$ of aſhes, and gave a yellow-black glaſs interſperſed with opake blueiſh white veins.

No. 6. conſiſted of $\frac{1}{3}$ baſalt, $\frac{1}{3}$ of refuſe ſoda, and $\frac{1}{3}$ of ſand. It gave a fine tranſparent green-yellow glaſs, very well melted, of a fine poliſh, and which would have been excellent for bottles.

No. 7. was ſimply the ſand of the river Orb in the neighbourhood, which appeared by inſpection to contain a large proportion of baſaltic earth. It melted well and gave a very good bottle glaſs.

The analyſis of baſalt ſhews that it is very well fitted both for fuſion *per ſe*, and to act as a flux of conſiderable power, for (as mentioned under that article) it conſiſts of about 45 per cent. of ſilex, 16 of alumine, from 16 to 20 of oxyd of iron, 9 of lime, and from 2.6 to 4. of pure ſoda, of which the three laſt are all very powerful fluxes. Many other minerals contain even more ſoda, ſuch as the Klingſtein, which contains about 8 per cent. of this alkali, but having much leſs lime and oxyd of iron it is much leſs fuſible. The colour of all the glaſſes into which baſalt enters largely as a conſtituent is generally of a deep olive green paſſing to deep yellow, and in maſs almoſt yellow, nor is it probable that this colour could be materially corrected. The glaſs is well aſcertained to be ſpecifically lighter than common green bottle glaſs but at the ſame time tougher, ſo as to bear harder blows without breaking, two

[k] Encyclop. Method. Article Verre.

very important advantages, and the quantity of alkali contained and that required to bring the whole to a workable ſtate is ſo ſmall as probably to enable this glaſs to reſiſt all corroſive liquors, at leaſt as well as any other known kind of glaſs.

Plate glaſs is that moſt beautiful and perfect glaſs of which all the kinds of mirrors and looking-glaſſes are compoſed, and of which the larger articles are wrought, not by blowing as every other glaſs article is, but by *caſting* the melted glaſs on a flat table.

The Venetians were long in the ſole poſſeſſion of the art of making mirror-glaſs, but by them it was only manufactured by blowing, nearly in the way deſcribed under crown or window glaſs, and much of the common mirror glaſs is ſtill prepared in this way.

In 1665 under the miniſtry of the great Colbert a company for *blown-mirror glaſs* was firſt eſtabliſhed near Cherbourg in Normandy, on the plan of the Venetian manufacture, but the beautiful art of caſting glaſs was invented in France about 1688, by one Abraham Thevart, and a company was ſoon eſtabliſhed for this branch of manufacture which was firſt carried on at Paris, and ſoon after removed to St. Gobin, where it ſtill exiſts in full activity, and undiminiſhed reputation.

The plate-glaſs cannot be made by blowing of a larger ſize than about fifty inches to be perfect, but by the ingenious ſubſtitution of caſting it may be made ſo large and at the ſame time ſo perfect, that ſcarcely any other limits can be ſet to the poſſible ſize of theſe plates than the heavy expence of the manufacture, in all its parts. As large plates as nine feet long, and wide in proportion, have been manufactured.

As this art of caſting glaſs requires more care in the choice of materials and nicety in the proceſſes of manufacture than moſt other branches of glaſs-making, ſome more detailed account may be given of it as carried on in France, as far as it can be underſtood without reference to plates.

The materials of the fineſt plate glaſs are white ſand, ſoda, and lime, to which are added manganeſe and zaffre, or any other oxyd of cobalt for particular colouring purpoſes, which will be preſently deſcribed. The ſand is of the fineſt and whiteſt kind, and is previouſly paſſed through a wire ſieve of moderate cloſeneſs into water where it is well ſtirred about and waſhed till all dirt and impurity is got rid of. The ſharpeſt grained ſand is preferred, and indeed it is found that the grains of moderate ſize melt with the alkali ſooner than either the very fine duſt or the larger fragments, in the former caſe the ſand clotting together without mixing freely with the alkali, and in the latter the grains taking a longer time to diſſolve on account of their bulk. The alkali uſed here is always ſoda, and there ſeems good reaſon to prefer this to potaſh, as glaſſes made with ſoda are found to be ſofter and to flow thinner when hot, and yet to be equally durable when cold, and in caſting a large plate of which the perfection is to be without ſtreak or bubble it is obvious of how much importance it muſt be to have it flow extremely liquid from the pot. Beſides, the neutral ſalts with the baſis of ſoda which conſtitute the glaſs-gall in this inſtance, ſuch as the muriat and ſulphat of ſoda, appear to be diſſipated more readily by the fire than the correſponding ſalts of potaſh. The ſoda uſed here is conſiderably pure, or ſuch as is ſeparated from the rough aſhes of barilla, and other ſoda plants by lixiviation.

Lime is of conſiderable uſe here and adds much to the fuſibility of the other materials, ſupplying in this reſpect the uſe of litharge in the flint-glaſs. Too much lime however impairs the colour and ſolidity of the glaſs. About $\frac{1}{15}$ of the whole is as much lime as can be uſed with propriety, and ſome uſe as little as $\frac{1}{24}$.

The colouring or rather decolouring ſubſtances uſed are *azure*, or cobalt blue, and manganeſe. The latter is here in the ſtate in which its effect is that of giving a ſlight red tinge, which mixes with the blue of the cobalt and the natural ſlight yellow of the other materials, and altogether are found when properly proportioned to neutralize each other ſo that ſcarcely any definable tint remains.

Beſides theſe ingredients there is always a great quantity of fragments of glaſs ariſing from what is ſpilt in the caſting and the ends cut off in ſhaping the plates, which are made friable by quenching in water when hot and uſed in this ſtate along with the freſh materials.

With regard to the proportions of the ingredients very conſiderable latitude may be allowed. The quantity of ſoda is a good deal more than neceſſary merely to produce a good glaſs, as one of great fuſibility is required. The following doſes are found to produce a very fine glaſs: 300 lbs. of ſand; 200 lbs. of ſoda; 30 lbs. of lime; 32 ounces of manganeſe; 3 ounces of azure; and 300 lbs. of fragments of glaſs.

It does not appear whether or not any other fluxes are uſed, though there ſeems to be ſome ſecrecy obſerved in this reſpect at the manufactory of St. Gobin. It is conſtantly aſſerted and with much probability, that borax is alſo uſed in ſmall quantity. This is in itſelf highly probable, as the very thin watery fuſion which this flux gives to vitrifying matters ſeems peculiarly wanted in glaſs intended to be caſt, and probably this addition would enable the manufacturer to uſe potaſh with as much advantage as ſoda where it happened to be cheaper.

Of the above materials the ſand, ſoda, lime and manganeſe are firſt mixed together with more care than for ordinary glaſs, and are fritted in ſmall furnaces built for this expreſs purpoſe, the heat being gradually raiſed to a full red-white, and kept at this point with frequent ſtirring till the materials undergo no further change, nor give any kind of vapour. The azure and the glaſs fragments being already perfectly vitrified are not added till juſt at the end of the proceſs which laſts about ſix hours.

The glaſs-houſe for this manufacture differs in ſeveral particulars from the common houſes for blowing glaſs. The furnace at St. Gobin is about 18 feet long and 15 wide, made of good bricks. They are particularly diſtinguiſhed from the common furnaces by containing two kinds of crucibles, the larger ones called *pots* are in the form of an inverted and truncated cone, and in theſe the glaſs is melted. The other ſet of crucibles are ſmaller ones called *cuvettes*, the capacity of which is not more than a ſixth, or where very large plates are caſt, a third, of the pots, and are kept in the furnace empty, but quite hot, till the glaſs is ready for caſting, when they are filled out of the pots, and drawn out of the furnace on an iron cradle to the heated table or bed on which the glaſs is caſt. Both the pots and the cuvettes are of the ſame material, of good refractory clay. Another eſſential part of this furnace is the flat table (of which there is one correſponding with each pot) on which the glaſs is caſt. Theſe tables are of ſmooth thick copper plate about ten feet by ſix, ſtrongly ſupported by maſonry; and contiguous to each table on the ſame level are flat ovens, heated from underneath, upon which the glaſs when caſt and ſufficiently cooled, may be ſlid without difficulty from off the copper table and there annealed. The tops of the flat ovens and the tables are on a level with the correſponding opening of the furnace whence the cuvettes are withdrawn. The fuel uſed is wood, and the kind which makes the largeſt and brighteſt flame, but without giving much reſinous ſmoke is preferred. It requires about thirty-ſix hours of ſtrong heat from the time of filling the pots till the glaſs is fit for caſting.

The proceſs of filling the pots and the appearances that take place in the melting materials, the riſing of the glaſs-gall, refining, &c. need not be deſcribed, being the ſame as in other glaſs-making.

When the glaſs is thoroughly melted and fine, the proceedings are in a general way as follows: the cuvette (which has been previouſly emptied of all the looſe glaſs and foulneſs which may have adhered to it and again made quite hot in its place in the furnace) is filled in the following way; the workman takes a copper ladle about ten inches in diameter and fixed to an iron handle ſeven feet long, plunges it into the glaſs pot (the contents of which have been previouſly ſcummed carefully) brings it up full of the melted glaſs, and empties it into the cuvette, the ladle being ſupported at the bottom by a ſtrong iron reſt, held by two other workmen, leſt the red-hot copper ſhould bend and give way with the weight of the glaſs within. The cuvette being filled by repeated lading is then ſuffered to remain in the furnace for ſome hours, that the bubbles formed by this diſturbance of the glaſs may have entirely diſappeared, and the ſamples taken out from time to time become quite clear and limpid. The door of the furnace is now opened, the cuvette is ſlid out and pulled upon a low iron cradle and immediately drawn on to the ſide of the copper table, previouſly heated by hot aſhes and wiped quite clean. The cuvette full of the melted glaſs is then carefully ſcummed by a broad *ſabre*, or copper blade ſet in iron, which carries off with it every impurity at the ſurface. The reaſon of uſing copper for this as for the ladle and caſting table is that it does not diſcolour the hot glaſs as iron does. The cuvette is then hoiſted up by a tackle and iron chains, and overſet upon the copper table, on which a thick flood of melted glaſs flows and ſpreads in every direction to an equal thickneſs. It is then made quite ſmooth and uniform at the ſurface, by paſſing over it while ſtill quite hot a heavy hollow roller or cylinder of copper made true and ſmooth by turning after it is caſt, and weighing about 500 lbs. At the ſame time the empty cuvette is returned by the iron cradle to its proper place within the furnace. The edges of the copper table overhang a reſervoir of water into which the

waſte glaſs falls in drops, and is uſed for the next melting. The number of workmen required for the whole proceſs of caſting is at leaſt twenty, each of which has his ſeparate employment.

The plate being caſt, the inſpector examines whether there are any bubbles on any part of the ſurface, and if found, the plate is immediately cut up through them. The plate being now ſo far cool as to be ſtiffened is ſlid by an iron inſtrument from the caſting table to the contiguous annealing oven previouſly well heated, and is carefully taken up and ranged properly within it. Each oven will contain ſix entire plates, and when full, all the openings are ſtopped with clay and the plates allowed to remain there for a fortnight to be thoroughly annealed.

When fit to be taken out of the annealing oven they are ſent away to receive all the ſubſequent operations of poliſhing, ſilvering, &c. but firſt their edges are cut ſmooth and ſquared. This is done by a rough diamond which is paſſed along the ſurface of the glaſs upon a ſquare ruler in the manner of glaziers, and made to cut into the ſubſtance of the glaſs to a certain depth. The cut is then opened by gently knocking with a ſmall hammer on the under ſide of the glaſs juſt beneath, and the piece comes off, and the roughneſſes of the edges are removed by pincers. The plate is then finiſhed as far as the glaſs-houſe buſineſs is concerned and is carefully removed to the warehouſe.

The ſubſequent operations of poliſhing and ſilvering may here be added in a few words.[1] The plate is firſt exactly ſquared by the diamond in the way mentioned above, and minutely examined as to any flaws or faults which may be found. The next ſtep is to grind off all the inequalities and roughneſſes of ſurface previous to the poliſhing. This is done on both ſides by ſand and water. For this the plate is laid on a thin plate of freeſtone or on a long wooden frame, of about the ſame ſize with it and cemented ſtrongly thereto by Paris plaſter. Another plate is alſo cemented in the ſame manner and laid upon the lower plate, and wet ſand is interſperſed between the two. The plates are then made to rub againſt each ſteadily and evenly by a kind of hand mill, the wheel of which is worked by a man, or ſometimes in large plates by two men, who can regulate the preſſure of one on the other as it may be judged proper. In proportion as the ſurfaces of the plates wear down the ſand is uſed ſucceſſively finer, being previouſly ſifted and ſorted for the purpoſe. In general the workmen avoid rubbing two abſolutely rough ſurfaces on the other for fear that the great jarring of the friction ſhould produce ſhakes and flaws in the glaſs, but a half ground plate is rubbed on a freſh ſurface and ſo on ſucceſſively.

When one ſide of the plate is done, the plaſter which cemented it is picked off, the plate turned, and the oppoſite ſide ground in the ſame manner. Towards the end of the grinding the preſſure is encreaſed by loading the upper plates with flat ſtones of different thickneſſes. This proceſs laſts about three days, and great attention is paid to finiſh them with ſurfaces perfectly flat and parallel, which is determined by the ruler and plumb-line. The ground ſurfaces are now uniformly worn by millions of ſcratches, and therefore nearly opake unleſs held up to the light, but ſtill very far from having the requiſite fineneſs to receive the poliſh. This further grinding is done by emery of different degrees of fineneſs, the preparation and ſorting of which is done in the following very ſimple manner. A large quantity of rough emery is put into a veſſel with water and ſtrongly ſtirred about till the whole is mixed. But as emery is abſolutely inſoluble in water the whole will again be depoſited in ſucceſſive layers, the coarſeſt particles ſinking firſt, and the others afterwards in the inverſe degree of their fineneſs. By ſtanding about twenty minutes and then pouring off the ſupernatant liquor, the latter holds ſuſpended only the very fineſt particles which again ſeparate by reſt for a longer time. More water is then added to the veſſel, the emery ſtirred again, and now allowed to remain at reſt only for fifteen minutes, and the ſupernatant turbid liquor again poured off. This furniſhes by reſt an emery of the ſecond degree of fineneſs. The ſame is repeated twice more at the different times of about five minutes and half a minute, by which two other ſorts are obtained. The wet emery from all theſe liquors is ſeparately heated over a ſtove to evaporate the water, and when nearly dry is made up into balls in which ſtate it is diſtributed to the workmen.

The plates are then further ground on both ſides with two or three emerys, beginning with the coarſeſt and are finiſhed with great care. They are now perfectly even, with a deadening or opacity on their ſurface, but ſo fine that no

[1] Encyclop. Meth. Journ. and Polytech. pt. 5.

ſcratches can be perceived. In this ſtate they are again examined, and if any material defects ſtill remain below the ground ſurface, they are cut up with the diamond into ſmaller plates with the greateſt economy poſſible, the diamond now dividing them with much greater eaſe than before, both on account of the quantity of ſubſtance of glaſs removed and the uniformity of the ſurface.

The next proceſs is that of poliſhing both ſurfaces to that perfect brightneſs which is ſeen in finiſhed mirrors, ſo that the rays of light may paſs through unimpaired to the ſilvering on the poſterior ſurface and be reflected again from thence according to the laws of catoptrics. The ſubſtance uſed to give this laſt poliſh is colcothar, imported from this country and called *rouge d'Angleterre* or *Potée*. It is the reſidue left in the retorts of the aqua-fortis makers, and when well waſhed and levigated conſiſts of little elſe than a red and perfect oxyd of iron.

The poliſhing inſtrument is a block of wood covered with ſeveral folds of black cloth with carded wool between each fold ſo as to make a firm elaſtic cuſhion. This block has a handle for the workman to hold; for the whole of this part is done by hand and not by machinery, as the latter would work too uniformly, and not allow of that variation of preſſure and thoſe finiſhing touches which are required to bring every part of the glaſs to exactly the ſame height of poliſh. But to encreaſe the preſſure of the poliſher without fatiguing the workman, the handle is lengthened by a wooden ſpring bent to a bow and three or four feet long, which at the other extremity reſts againſt a fixed point in a beam placed above. The plate being fixed on the table by plaſter he then moiſtens the poliſher with a wet bruſh, covers it with colcothar and begins his operation by working it backwards and forwards over the ſurface of the plate. Much practical ſkill and dexterity is required to give an uniform and high degree of poliſh over the ſurface of a large plate, as it muſt be done by ſeparate portions and the finiſhing touches given with great care. The glaſſes of moderate ſize are compleated in four portions from corner to corner, the centers of which intermingle ſo as to leave no part untouched, but the larger glaſſes require additional poliſhing in the center. When one ſide is completed and the reverſe is about to be done, the poliſhed ſide, now the undermoſt, is entirely covered with the red colcothar to prevent the dazzle reflected from the white plaſter which would prevent the workman from judging ſo accurately of the ſtate of the ſurfaces on which he is employed. When both ſides of the glaſs are thus brought to the ſame perfection of poliſh, the operation is finiſhed by inſpecting the glaſs, firſt cleaning both ſurfaces, and laying it, each ſide alternately upwards, upon a dark blue or black cloth admitting only a moderate light, and if any part appear leſs highly finiſhed than the reſt it is retouched by a ſmall hand-poliſher and colcothar as before.

When a number of ſmaller pieces of glaſs, ſuch as are uſed only for chamber or ſimilar mirrors are to be poliſhed, they are laid together on the table and ſeveral of them poliſhed at a time. But as theſe conſiſt of pieces often of unequal thickneſs, though their ſurfaces have been rendered perfectly flat by the previous grinding, if they were ſimply placed ſide by ſide and fixed on the table by plaſter as uſual, the poliſher would not work well over ſuch a variety of heights, and would act chiefly on the edges of each piece of plate. Therefore they are all firſt arranged on a large ſmooth plate, finiſhed all but the poliſhing, and previouſly wetted, and plaſter is poured upon them by which they are fixed together, and then when taken off, the ſurfaces which were in contact with the plate are perfectly level with each other, and the poliſhing goes on with the ſame eaſe as on an entire plate.

What is termed *ſilvering* of mirrors, is applying to the poſterior ſurface a coating of quick-ſilver, which metal when perfectly bright and brilliant reflects the rays of light with great accuracy and beauty. But as this fluid metal could not be alone applied without great inconvenience, it is firſt made to adhere by a partial amalgamation to the ſurface of a ſheet of tin-leaf, and then by the help of preſſure is applied cloſely to the glaſs in a very thin lamina. It is therefore properly a thin ſheet of tin fully impregnated with mercury which is the reflecting ſurface.

The management of the ſilvering is extremely ſimple. A perfectly flat ſlab of ſmoothed free-ſtone (or ſometimes of thick wood) a little larger than the largeſt plate, is incloſed in a ſquare wooden frame or box open at top, and with a ledge riſing a few inches on three ſides and cut down even with the ſtone on the fourth. A ſmall channel or gutter is cut at bottom of the wooden frame, ſerving to convey the waſte mercury down into a veſſel below, ſet to catch it. The ſlab is alſo fixed on a centre pivot, ſo that one end may be raiſed by wedges (and of

courſe the other depreſſed) at pleaſure when working freely in the box.

The ſlab being firſt laid quite horizontal, and covered with grey paper ſtretched tight over it, a ſheet of tin-foil, a little bigger than the plate to be ſilvered is ſpread over it, and every creaſe ſmoothed down carefully; a little mercury is then laid upon it, and ſpread over with a tight roll of cloth, immediately after which as much mercury is poured over it as will lie on the flat ſurface without ſpilling. That part of the ſlab which is oppoſite the cut-down ſide of the wooden frame, is then covered with parchment, and the glaſs plate is lifted up with care and ſlid in (holding it quite horizontally) over the parchment, and lodged on the ſurface of the ſlab. The particular care required here is, that the under ſurface of the glaſs ſhould from the firſt juſt dip into the ſurface of the mercury (ſkimming it off as it were) but without touching the tin leaf in its paſſage which it might tear. By this means no bubbles of air can get between the glaſs and the metal, and alſo any little duſt or oxyd floating on the mercury is ſwept off before the plate without interfering. The plate being then let go ſinks on the tin-foil, ſqueezing out the ſuperfluous mercury, which paſſes into the channel of the wooden frame above-mentioned. The plate is then covered with a thick flannel, and is loaded over the whole ſurface with lead or iron weights, and at the ſame time is tilted up a little, by which ſtill more of the mercury is ſqueezed out. It remains in this ſituation for a day, the ſlope of the ſtone ſlab being gradually increaſed to favour the dripping of the mercury. The plate is then very cautiouſly removed, touching it only by the edges and upper ſide, and the under ſide is found uniformly covered with a ſoft paſty amalgam conſiſting of the tin-leaf thoroughly ſoaked with the quickſilver, and about the thickneſs of parchment. It is then ſet up in a wooden frame, and allowed to remain there for ſeveral days, the ſlope of its poſition being gradually encreaſed, till the amalgam is ſufficiently hardened to adhere ſo firmly as not to be removed by ſlight ſcratches, after which the plate is finiſhed and fit for framing.

It is a conſiderable time before the amalgam has acquired its utmoſt degree of hardneſs, ſo that globules of mercury will often drip from new mirrors ſome time after they have been ſet up in rooms, and violent concuſſions of the air, ſuch as from the firing of cannon, will often detach portions of the amalgam. Theſe can never be perfectly replaced by any patching, as the lines of junction with the old amalgam will always be marked by white ſeams ſeen when looking into the glaſs.

Of working Glaſs with the Lamp and Blow-Pipe.

A great variety of ſmall articles of glaſs for philoſophical purpoſes, ſuch as thermometers and barometers, and many ingenious toys, are made out of glaſs tubes by the blow-pipe, and ſome ſhort account of the general method of proceeding may here be added.

The uſual apparatus of the glaſs lamp-blowers is very ſimple. It conſiſts of a ſolid table at the bottom of which is fixed a double bellows with a foot-board, that the artiſt may work it with his foot and keep both his hands at liberty, whence proceeds a pipe which conducts the blaſt to the lamp, which is a large bundle of cotton thread lying in a tin veſſel of a horſe-ſhoe ſhape and fed with lumps of tallow heaped up beſide it. Theſe are from time to time drawn forwards into the flame, to keep up the combuſtion. A ſmall chimney hangs a little way over the lamp to carry off the ſmoke. The blaſt-pipe comes up in front of the table where the artiſt ſits, and drives the jet of flame in a contrary direction to his body, ſo that he is not in the leaſt incommoded by it. All the reſt of his apparatus conſiſts of an aſſortment of glaſs tubes, of different bores and thickneſſes of glaſs (made at the glaſs-houſe, by pulling out rather ſuddenly a bottle of blown glaſs when ſtill quite ſoft) and two or three very ſimple iron tools, ſuch as ſmall forceps, files, &c. Any other method of working the blow-pipe may be adopted that will give a very large and powerful flame. The flame when in full vigour is a jet of fire about four inches long, not ſharp-pointed, but like a blunt rounded ſpear-head, which near its extremity is of a clear light blue, and beyond, of a pale yellow. The blue part is the hotteſt. As general rules for managing the working, the tubes ſhould never have any moiſture introduced into them, and ſhould be well dried on the outſide before working. They are to be heated gradually (with more care in proportion to the thickneſs) firſt by being held in the flame of the lamp without blowing, and then at the edge of the outer yellow part of the jet of flame, and ſlowly brought to fuſion. The flame is ſtrong enough to bring to a very white-red heat a ſolid maſs of glaſs about as big as a child's playing marble, or even larger, which when blown out very thin, will make a bulb of the capacity of full three

ounces, and this is nearly the extent of the power of the common lamp-blowing. But the bulbs for thermometers, or other philoſophical purpoſes are much leſs. Two or three of the commoneſt operations may be deſcribed.

To ſeal a tube hermetically, if ſmall, it is ſufficient to hold it in the flame for a little time ſlowly turning it round, when the end will melt, and falling in, will cloſe the cavity with a neat button. This may be aſſiſted by puſhing the ſoftened ends in towards the common center with an iron needle. But if the tube be very large, this button would be too clumſy, and being thick would be in danger of breaking on cooling. It is therefore neceſſary to leſſen the quantity of glaſs, which is done in the following way: ſoften the end of the tube in the flame, and apply to it a piece of another tube of nearly the ſame ſize (fragments of tubes being always abundant in this buſineſs) which will ſtick firmly to it. Then ſoften the tube to be ſealed a little higher up than the point of junćture, and pull the two ſlowly in contrary direćtions till they ſeparate. The tube will then draw out at the heated part into two ſhort thin funnels, and a little turning and management of the flame will readily ſeal that which is wanted, leaving the joined ends and about half an inch of the lower part of the tube on the waſte piece.

To bend a tube, if of a narrow bore and the glaſs is pretty thick, it is only neceſſary to hold it in the weaker part of the flame, and ſoften it for about an inch or two of its length, and bend it ſlowly into the required ſhape. In this way barometer tubes are bent. But if the tube be wide, and the glaſs thin, this way of bending entirely deſtroys the cylindrical form of the bore at the bent part, making a double flattening. To avoid this, firſt ſeal up one end of the tube, and then whilſt bending it at the required part, blow ſteadily and gently into the open end, and the preſſure of the breath will counteract the falling in of the ſides of the bending portion, and keep the bore cylindrical. The cloſed end is then cut off by the file, to do which make a deep ſcratch with one edge of a fine three-cornered file on the part intended to be cut, then break the tube with a ſmart pull in that direction in which the ſcratched part will be outermoſt, and it will ſeparate in general with great accuracy at this point.

To join two tubes, heat them both in the flame, and apply them together when white hot, turning them round to finiſh the conſolidation, or elſe to avoid the thick ring of glaſs which this produces, previouſly cloſe one end of one tube, and when the two are fully joined blow into the open end of the other tube, and pull them out a little at the point of junćture, till an equal cylinder is formed.

To form a bulb (of a thermometer for example) chooſe a tube of a very equal bore, ſeal the end in the uſual manner, and to collect a greater maſs of glaſs at the end, preſs upwards on it while quite hot with any iron inſtrument, ſo as to conſolidate and ſhorten it a little; let it remain in the hotteſt part of the flame till the lump of glaſs is quite white hot, then remove it, put your lips to the open end without loſs of time, holding it with the hot part loweſt, and blow moderately and ſteadily. The lump of hot glaſs will immediately open into a bulb, the ſize of which can be regulated at pleaſure.

Glaſs may be ſpun out into threads of almoſt indefinite minuteneſs by means of the blow-pipe. When no thicker than fine hair, it is extremely flexible and elaſtic, and if ſtill finer it may be wound almoſt like common thread without breaking. The way of doing it is very ſimple. A piece of glaſs tube is heated in the lamp, and the end drawn out into a thread by means of another piece of glaſs cemented to it. When a fine thread is once drawn, the end is carried round a reel or wheel two to three feet in diameter, and by turning the wheel and continuing to heat the tube, an endleſs thread is drawn out, winding round it as long as the artiſt pleaſes or the glaſs laſts. The quicker the wheel revolves, and the hotter the glaſs is kept, the firmer is the thread, which may thus be made as delicate as a ſingle ſilk-worm's thread, with extreme flexibility. Different coloured threads are made in this way by uſing very deeply coloured glaſſes inſtead of common glaſs.

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A ſingular change occurs in the texture of glaſs, more particularly of green bottle glaſs, made only of ſand, lime, and ſaline aſhes, when expoſed for ſome time to a moderate red heat, or any higher temperature, but below its melting point. This is peculiarly obſervable when it has been in contact with ſand, and hence it frequently takes place in green glaſs retorts long expoſed to a high heat in ſand-bath diſtillations. Neuman appears the firſt who noticed this change, which was afterwards examined more at large by Reaumur, and from the porcellanous texture which the glaſs aſſumes when thus changed, it has been commonly called *Reaumur's porcelain*. This ingenious philoſopher had the idea that much advantage might be made of this fact in rendering glaſs much

tougher and leſs liable to crack from changes of heat and cold. No uſe however has been made of it in manufacture, but as a curious chemical or phyſical phenomenon it deſerves further notice.

Dr. Lewis made the following very valuable experiments on this ſubſtance.[t] A number of pieces of common quart bottles were put into crucibles with white ſand poured over them, and put into a proper furnace where they were heated for many hours, and pieces withdrawn from time to time to examine the progreſs of the change. The pieces that were taken out, after many hours heating, but *below redneſs*, did not appear to have ſuffered any change whatever. In a low red heat the change went on though very ſlowly, but in a ſtrong red heat approaching to whiteneſs, juſt not ſufficient to melt the glaſs, the change went on pretty faſt, and in two hours the glaſs had aſſumed the appearance of porcelain, the change beginning at each ſurface and ſpreading gradually to the middle.

The glaſs firſt became blueiſh on the ſurface, and, when held to the light, yellowiſh, and with a very ſenſible diminution of its tranſparency. After this it gradually became white and opake, and the texture was no longer vitreous, but fibrous, and the fibres diſpoſed nearly parallel to each other. By degrees the glaſs became throughout opake and fibrous, and the colour of a dun white; the fibres were arranged regularly from the ſides to the middle, where the fibres from the two ſides meeting, formed a kind of partition, in which occaſionally were pretty large cavities. A longer continuance of fire induced a further change of texture, the fibres became divided or cut into grains at the outer ends and gradually through their whole length, and the whole ſubſtance changed in texture from *fibrous* to *granular*, like common porcelain. By a ſtill further continuance of fire the grains, at firſt fine and gloſſy, grew larger and duller, from being very compact became porous, and at laſt a friable ſubſtance like a ſlightly cohering maſs of white ſand, not eaſy to be diſtinguiſhed from the ſand in which it was imbedded.

Glaſs thus changed whilſt it remains in the fibrous ſtate, is conſiderably tougher and harder, ſo as to give abundant ſparks with ſteel, which common green bottle glaſs will hardly do, to cut all common glaſs with eaſe, and ſcarcely to be ſcratched by the file. It will bear alſo to be plunged ſuddenly from freezing to boiling water, without cracking, and at the ſame time its texture is ſo denſe that no acrid liquors whatever either corrode it or tranſude through it. The circumſtance which the moſt prevents its uſe in manufacture is, that though the inner texture is fine and white, the outer is coarſe and dirty-looking. When the heat is ſo long continued that the texture changes from fibrous to granular, it again becomes ſoft, no longer gives fire with ſteel, and loſes its coheſion.

Another important circumſtance to be obſerved is, that when this fibrous porcellanous glaſs is expoſed to a very ſtrong heat it melts into a ſemi-tranſparent maſs, drawing out in ſtrings, which on breaking are now no longer fibrous, but have *returned to the vitreous ſtate*, and at the ſame time again becomes no harder than the glaſs from which it was originally made. However it does not melt ſo eaſily as the glaſs itſelf, and the longer it is cemented the more difficult of fuſion it becomes, ſo that the granular porcelain requires a much higher heat for melting than the fibrous.

Dr. Lewis repeated the experiments, imbedding the glaſs in a variety of ſubſtances inſtead of ſand, ſuch as bone-aſh, charcoal, chalk, &c. but in all the change of texture was the ſame, the outer colour alone being affected. He then heated the glaſs by itſelf, being ſtuck up with a little luting in the middle of the crucible, and therefore touching nothing with the part above the luting. The ſame change however took place, though more ſlowly, and with ſome inconvenience from the falling in of ſome of the pieces when ſoftened by the heat. The ſand therefore has little other effect than to ſupport the glaſs during the proceſs, and prevent it from loſing its ſhape. Another important fact to the explanation of the cauſe is that the glaſs does not ſenſibly loſe or gain weight in the whole converſion from the vitreous to the fibrous ſtate.

Mr. Gregory Watt, in his moſt valuable paper on Baſalt,[u] very happily brings this porcellanous change of glaſs as an illuſtration of his important poſition, namely, that bodies whoſe fibres have a natural tendency to a cryſtalline arrangement, or a polarity, when vitrified by a ſufficient heat and cooled haſtily in the vitreous ſtate, are able ſubſequently to return to their natural cryſtalline arrangement of fibre when expoſed to a heat merely ſufficiently to ſoften the texture, though not enough for fuſion. This, in the inſtance of baſalt, he ſhews by the ſingular cryſtallizations formed in the cells of

[t] Commerce of the Arts.

[u] Phil. Tranſ. for 1804.

fuſed baſalt, long after it had loſt the liquidity of fuſion. The circumſtance of no material change occurring in the weight of glaſs by this converſion into the fibrous ſtate, ſhews inconteſtibly that it cannot be owing either to any thing gained during the proceſs, nor to any material loſs of the alkali, and this is alſo rendered manifeſt by its return to the vitreous ſtate and vitreous qualities when again melted. This too may again be porcellanized in the ſame way, and again be melted into glaſs, and ſo on alternately.

Glaſs has been often found cryſtallized quite at the bottom of the pots, and in places where it has cooled undiſturbed for a length of time. This is particularly the caſe in that maſs of refuſe and ſpilled glaſs, with aſhes, melted drops from the clay of the furnaces and pots, &c. which falls down behind the pots in the furnace.[x] This is generally raked out, but part of it remains, and when the fire is let to go out, and the furnace is become uſeleſs, theſe cryſtallizations are uſually found here. They are found in all kinds of glaſs, but leſs often in the fine flint and the very ſaline glaſſes, than in the coarſer green and crown glaſſes.

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Of Coloured Glasses.

The metallic oxyds when mixed with any of the glaſſes, diſſove in them with eaſe at a melting heat, and always change the colour more or leſs, ſometimes producing very beautiful compounds, which when well prepared, have a luſtre and richneſs of colour ſtrongly reſembling that of the natural gems, though in an inferior degree. The buſineſs of making theſe coloured glaſſes or artificial gems, is carried on to a very great extent in the manufacture of a variety of ornaments, and though much of the management remains a ſecret in the hands of the artiſts, a good deal of valuable matter has been made public by the labours of Neri,[a] Kunckel,[b] Margraaf,[c] Fontanieu,[d] and many other practical chemiſts.

It is very eaſy for any perſon at all uſed to chemical experiments to repeat moſt of theſe in the ſmall way, with ſufficient ſucceſs to ſatisfy himſelf of the leading facts, though for the purpoſe of manufacture more care in the choice and preparation of the materials, and a greater length of time in the melting part is required than moſt experimenters chooſe to beſtow.

It may be premiſed too that the art of making coloured *Enamels* is eſſentially the ſame as that of coloured glaſſes, the chief difference being that in the former caſe the *ground* or vitreous ſubſtance that receives the colour is an opake enamel glaſs, and in the latter a clear tranſparent glaſs. The way of preparing the enamel ground is deſcribed under that article. The colouring power of the metallic oxyds is alſo in many inſtances much affected by the degree of heat to which they are expoſed, and to the other ingredients with which they are mixed, and hence ariſe a good many precautions and niceties of management, many of which are only known to the practical artiſt. There ſeems good reaſon to ſuppoſe that much of this difference depends on the degree of oxygenation in which the colouring oxyd is left after the action of fire, or of the other ingredients. The phenomena that occur in the uſe of manganeſe have already been deſcribed, and ſomething ſimilar happens in uſing the oxyds of iron and ſilver. Sometimes a metallic oxyd may be ſo nearly reduced to the reguline ſtate, as not to be perfectly ſoluble in the glaſs, but only ſuſpended in it. This happens occaſionally with the oxyd of copper, which when perfectly oxydated gives a fine blueiſh-green, but when nearly in the metallic ſtate produces a brown-red and not perfectly tranſparent glaſs. There is alſo a mutual action of the oxyds upon each other, ſo that the glaſſes in which oxyd of lead enters, will not receive a red colour by iron, an effect which is not produced with the merely alkaline glaſſes. Much remains to be done on this very curious and entertaining ſubject of the colouring power of metallic oxyds, and it is only by a well-conducted ſcientific ſeries of experiments that the perplexing intricacy of many of the receipts of the articles on this ſubject can be reduced to certain rules.

In making coloured glaſſes to reſemble artificial gems, the glaſs which is to receive the colour (which is often called *cryſtal*) ought to unite the qualities of great purity, luſtre, and hardneſs, together with a ſufficient fuſibility to melt at a moderate heat thoſe oxyds that are in danger of being decompoſed by a high temperature. A vaſt variety of receipts have been given for ſuch a glaſs, and it appears that ſeveral ſorts are actually in uſe according to the price and object of the manufactured article. The glaſſes that poſſeſs the greateſt luſtre and are at the ſame time eaſily fuſible, are unqueſtionably thoſe in which the oxyd of lead enters very largely, and it appears that many of them are little elſe than oxyd of lead vitrified with a much ſmaller proportion of ſilex than is uſed

[a] Dartigues J. Phyſ. tom. 59. [b] Art. de la Verrerie. [c] Mem. Acad. Berlin, 1780. [d] Encycl. Method.

even in flint-glaſs, or any other ſpecies. To theſe borax is an important addition, and often arſenic and other fluxes are added. But it unfortunately happens, that the lead-glaſſes are at the ſame time the ſofteſt, and ſcratch with the greateſt eaſe. Hence it is the perfection of this art to find a compound, or manage any of the known compounds, in ſuch a manner as to unite both luſtre and hardneſs; in the former, the natural gems (the diamond excepted) may be very nearly equalled, but not in the latter.

Many of the older artiſts have had the idea that a harder glaſs would be obtained by making rock cryſtal the ſiliceous baſis than ſand, flint, or any other ſtone of this genus. But this ſeems totally unfounded, for when once diſſolved in a flux of any kind, the hardneſs of rock-cryſtal is irrecoverably loſt, as it is not an inherent property of this particular ſpecies any otherwiſe than as depending upon its natural aggregation, which of courſe is deſtroyed. Perhaps it may be ſomewhat purer than the fineſt ſand, or than powdered gun-flints, ſince theſe (the latter at leaſt certainly) contain a very minute portion of iron, which poſſibly, though not very probably, may a little affect the very fineſt colours. It is rendered friable by being heated red-hot and quenched in water in the ſame way that gun-flints are. It ſhould then be ground in a hard ſtone mortar, or in a mill, and not in any metallic mortar.

A few of theſe glaſſes may be here given from the directions of M. Fontanieu.

No. 1. Mix 20 parts of litharge, 12 of ſilex, 4 of nitre, 4 of borax, and 2 of white arſenic, frit them in a crucible and afterwards melt, then pour the whole into water, ſeparate any revived lead that may be found, and melt again.

No. 2. Mix 20 parts of ceruſſe, 8 of ſilex (powdered gun-flints) 4 of carbonat of potaſh, and 2 of borax. When melted, pour into water, and re-melt in a clean crucible.

No. 3. Mix 16 parts of minium, 8 of rock-cryſtal in powder, 4 of nitre, and 4 of carbonat of pot-aſh; melt and re-melt as before.

No. 4. Treat as above 24 parts of borax, 8 parts of rock-cryſtal, and 8 of carbonat of pot-aſh.

No. 5. Make a quantity of liquor of flints by fritting together 3 parts of alkali with 1 of rock-cryſtal, which diſſolve in water, and ſaturate with dilute nitric acid. Edulcorate and dry the ſilex which precipitates, and which is then in a very fine impalpable powder. Then melt it in a crucible with 1½ its weight of very fine ceruſſe, and pour the glaſs into water. Then break it down and melt it with $\frac{1}{12}$ its weight of borax, and pour into water as before. Laſtly melt this latter product with $\frac{1}{12}$ of nitre, and the reſult will be a very fine hard glaſs of extreme luſtre.

Of the above glaſſes, No. 1. will be extremely ſoft and fuſible, on account of the large proportion of flux, and it requires a very good crucible to withſtand the corroding effect for a number of hours. The crucibles are found to ſtand better if they are firſt lined with any common glaſs without lead, for which purpoſe a little of the glaſs, No. 4, may be moiſtened with water, rubbed over the inſide of the crucible, ſlowly and thoroughly dried and heated red-hot before the mixture is added, which will give it an uniform glazing. Silex requires to make a perfect and ſufficiently workable glaſs from 1½ to twice its weight of oxyd of lead, and a glaſs of this kind with a ſmaller quantity of oxyd of lead and a little other flux, will be very hard and brilliant, and will imitate the diamond when properly ſet, more than moſt other compoſitions.

The length of time required for fuſion of the coloured glaſſes, appears to be for the hard glaſſes or *paſtes*, at leaſt twenty-four hours, but the ſofter mixtures are thoroughly compleat in a few hours. In the glaſs, No. 4, the ſilex is firſt directed to be reduced to the ſtate of the greateſt purity, and the moſt impalpable powder, by previous fuſion with an exceſs of alkali, and precipitation by an exceſs of acid. It is ſeldom however that ſuch extreme nicety of preparation can be required, and probably finely powdered flints would anſwer as well, or even fine ſand. The proceſs of pouring the melted glaſs into water, and re-melting, is uſed to mix the ingredients thoroughly, and is found by experience to have its uſe.

We ſhall now proceed to the colouring matters which (one excepted) are all metallic oxyds. We ſhall firſt mention the effect of the ſeveral metals individually, and then the method of producing the particular colours.

Of Gold. This metal in the ſtate of great diviſion, and oxydated, has long been celebrated for giving to glaſs a moſt exquiſite purpliſh-red reſembling the ruby, and nearly equalling it in beauty. It is both the moſt expenſive and the moſt ſplendid of all the artificial gems or coloured glaſſes, but the management ſeems to be extremely difficult to enſure the compleateſt and moſt uniform ſucceſs, principally, as may be ſuppoſed, from the great tendency of gold to aſſume the reguline ſtate by mere heat, by any

carbonaceous vapour, or by hydrogen. The moſt celebrated and the commoneſt preparation of gold for giving a purple to glaſs and porcelain, is the *purple precipitate of Caſſius*, or gold precipitated from its nitro-muriatic ſolution, by, and together with, the oxyd of tin. The uſual way of making it is, to dilute very largely a ſolution of gold in aqua-regia (formed by about 3 parts nitric and 1 muriatic acid) and add to it drop by drop a very dilute nitro-muriat of tin, well ſaturated with this metal. The liquors immediately become of a purpliſh red colour (like Port wine and water) and by ſtanding, a precipitate of this colour with ſome varieties of ſhade, ſlowly ſubſides. A ſimilar precipitate alſo takes place with the nitro-muriat of gold and the pale muriat of tin, and alſo with great certainty by immerſing a ſtick of tin in the dilute ſolution of gold. Though the change of colour always takes place when the nitro-muriat of tin is uſed, the precipitate ſometimes fails to ſeparate without any apparent reaſon. This ſubſtance is a moſt intimate mixture of the oxyds of tin and of gold, but the preciſe ſtate of oxygenation of the tin is not well known, nor its exact uſe. It is certainly not eſſential to give the purple-red tinge to glaſs, ſince many other preparations of gold will produce it, in which not an atom of tin enters. Poſſibly the tin enables the gold to bear a longer continuance of heat, and a higher temperature, without reduction.

The precipitate formed by *metallic tin* and the ſolution of gold, may be ſuppoſed to be at a lower ſtate of oxygenation than where the nitro-muriat of tin is employed, and probably it is always uſeful to add a little nitre to the powder before mixing to prevent the partial reduction of the gold by the heat. Neither copper nor ſilver, in ſmall quantities, appear to injure the colouring power of gold.

Another preparation of this metal uſed in glaſs and porcelain colours, is the *fulminating gold*, prepared by precipitating this metal from its nitro-muriatic ſolution by ammonia. This preparation is known to explode moſt violently when raiſed to ſomewhat leſs than a tin melting heat, or even by moderate friction, but if kept for ſome time at a much lower temperature, being previouſly mixed with a fixed alkali, it loſes its fulminating property, and may be ſafely uſed. A more manageable preparation of gold is the precipitate from the nitro-muriat of gold, by carbonat of potaſh, which is a brown-red or yellowiſh powder, and is not fulminating provided the ſolution of gold be made with the muriatic acid, and not muriat of ammonia, for it is the preſence of ammonia that is eſſential to the fulminating property. For the fine porcelain carmines, this carbonated oxyd of gold, as well as the decompoſed fulminating gold, is mixed with luna cornea, and then with the proper quantity of ſaline flux, in which nitre and borax uſually enter.[a] The colouring power of theſe ſimple oxyds of gold, is nearly twelve times as ſtrong as that of the purple precipitate, another proof that the tin does not of itſelf add to the body of colour. An ingenious way of producing a moſt intimate admixture of the oxyd of gold with ſilex, is to add the nitro-muriatic ſolution of the metal to the liquor ſilicum, or ſilicited alkali, and, if neceſſary, to add a further quantity of any acid to ſaturate the alkali. The ſilex is then precipitated in very intimate combination with the gold, and when waſhed and dried, is fit to be uſed as a colour, when mixed with nitre and borax or any other flux.

Whenever the purple precipitate by tin is uſed, it appears to be the practice to add about $\frac{1}{6}$ of its weight of the perfect white oxyd of antimony by nitre, or elſe of the glaſs of antimony. This naturally gives a yellow, and it ſeems by experience to be a very important ingredient in the compoſition of the fine ruby glaſs. The particular rules for managing the fire in making this nice and difficult preparation, are known only to practical artiſts, but it can hardly be doubted that the peculiar riſk is of giving too much heat, and thereby of deſtroying the colour altogether. All kind of ſmoke and other vapours ſhould alſo be avoided. The fineſt ruby glaſs is ſaid to come out of the crucible, when compleat, quite colourleſs, but to aſſume its peculiar exquiſite tint as it cools.

Of Silver. All the oxyds of ſilver give naturally a yellow to vitreſcent mixtures, which appears to be very pure and beautiful, but is not often uſed in the coloured glaſſes on account of the eaſe with which it is deſtroyed by too much heat. It ſeems to be chiefly uſed in the tender porcelain and enamel colours, where the eye of the artiſt can always be upon his work, and the heat is lower and much more manageable. In the latter caſe the oxyd of ſilver is generally mixed with a ſmall quantity of alumine. The phoſphat of ſilver formed by adding the nitrat of ſilver to the phoſphat of ſoda, is alſo employed.[b]

Of Iron. The ſhades of colour produced by

[a] Brogniart, Journ. de Mines, No. 67. [b] Clouet.

the oxyds of iron are very numerous. In the general account of glaſs-making it was obſerved that a very ſmall portion of iron fully vitrified with a large body of glaſs gave different ſhades of green and yellow, and to this the colour of common green bottle glaſs ſeems to be owing. A larger doſe of iron gives a yellow after thorough vitrification, and a ſtill larger gives a browniſh black, which ſeems to be only a yellow very much concentrated, ſince this latter colour is again produced by diluting the browniſh-black with a greater quantity of uncoloured glaſs. The oxyds of iron alſo produce a red upon enamel and porcelain, but as it appears, this is only owing to imperfect vitrification, that is to ſay, it is only red as long as it is merely *ſuſpended* in the glaſs flux in a ſtate of extreme diviſion, for when by raiſing the heat a compleat fuſion of the oxyd is produced, the colour turns to yellow. This change is ingeniouſly prevented by combining the oxyd previouſly with alumine, by mixing the ſulphat of iron and alum together in ſolution, and precipitating both together by carbonat of potaſh, as mentioned under the article *Enamel*.

A great many preparations of iron for theſe purpoſes have been given, particularly the *ſaffron of mars*, the *ethiops*, and the red oxyd precipitated from any of the ſolutions, all of which will be mentioned under the article *Iron*. It does not appear however that there is any certain foundation for preferring one to the other, for even the perfect oxyd by nitric acid, and which is itſelf of a dark red-brown, when fully vitrified produces a yellow or brown according to the doſe, as well as any of the ſub-oxyds. Brogniart aſſerts that the preſence of the oxyd of lead ſingularly diſpoſes the perfect oxyd of iron to loſe its red or roſe colour, for which it is uſed in enamelling, when urged by ſtrong fire, but when no lead is preſent the colour is fixed.

Of Copper. All the oxyds and carbonated oxyds of copper produce a fine green when thoroughly vitrified with any kind of glaſs or flux, and this colour is one of the eaſieſt to produce in experiments in the ſmall way. There does not ſeem to be much reaſon for preference of one preparation over the other. Thoſe the moſt frequently employed are the carbonated oxyd produced by adding a carbonated alkali to the ſulphat of copper, and alſo the æs uſtum or copper oxydated and calcined ſimply by heat and acceſs of air. This metal however may be made to give a carmine red (or mixed with iron a full deep red) by adding to glaſs containing it a quantity of tartar when in compleat fuſion and working off almoſt immediately. The oxyd of copper muſt in this caſe be reduced nearly to the reguline ſtate. A greater continuance of the heat reſtores the green colour. The oxyd of copper is alſo often mixed with manganeſe and iron in the compoſition of the full-bodied black glaſs. This oxyd when combined with thrice its weight of alumine runs in a ſtrong heat into an opake red enamel.

Of Lead. The oxyds of lead naturally give a yellow tinge to glaſs, but only conſiderably ſo when in very large quantity. Their uſe as a flux has been repeatedly mentioned, and they will readily vitrify moſt compleatly in a moderate heat without addition, or will unite with any other vitrifiable matters and moſt powerfully aſſiſt their vitrification. This oxyd is ſeldom uſed directly as a colour, on account of the enormous proportion required, which ſhould be at leaſt three-fourths of the glaſs to give a yellow of any intenſity, and this would give a compound extremely ſoft and one that would powerfully corrode the crucibles.

Of Antimony. The perfect oxyd of this metal gives a full yellow to glaſs which is much uſed, both alone and in compound colours in which yellow is a neceſſary ingredient.

Of Manganeſe. The peculiar circumſtances attending the uſe of this metallic oxyd in glaſs-making have already been mentioned. When not in contact with carbonaceous matter the proper colour given by this oxyd to glaſs is a purpliſh-red, rather muddy when in full body, but ſtill very beautiful. It is almoſt always combined with nitre when thus employed. The colour is totally deſtroyed by all the arſenical ſalts as before mentioned, and therefore arſenic in any form ſhould be avoided when manganeſe is uſed as a colouring matter. It alſo is the principal ingredient in moſt of the black glaſſes.

Of Cobalt. The colour given by the oxyd of this metal is a fine deep blue, which is unalterable in any fire, and ſucceeds with any flux. The colouring power is alſo very intenſe. Zaffre is uſually employed for this purpoſe. Cobalt is alſo uſed for ſome of the finer blacks mixed with manganeſe and iron, and with the yellow of antimony and lead it compoſes a green.

Of Nickel. Though this oxyd is not actually uſed it may here be mentioned that the oxyd gives a violet-blue glaſs with fluxes of potaſh and to thoſe glaſſes in which it largely enters, but not with ſoda or borax. Klaproth has fully

aſcertained this in his analyſis of the Chryſopraſe,[c] which, from its giving a blue to potaſh glaſs, was thought to contain cobalt, but this is not the caſe, the colouring matter being nickel. Thus 1 part of the rough chryſopraſe, and 2 parts of carbonat of potaſh fuſed into a violet-blue glaſs; and 80 parts of ſilex, 60 of carbonat of potaſh, and 3 of oxyd of nickel from the chryſopraſe, alſo gave a violet-blue glaſs. The ſame reſult was given by uſing an oxyd of nickel from a known ore of that metal. Equal parts of the chryſopraſe and of carbonat of ſoda gave a tourmaline-brown glaſs nearly opake. Equal parts of chryſopraſe and calcined borax gave a brown tranſparent glaſs: and 60 parts of ſilex, as much borax, and 3 parts of oxyd of nickel, alſo gave a clear light brown glaſs. Silex, phoſphoric acid, and oxyd of nickel in the ſame proportions gave a honey-yellow glaſs but not quite clear.

Of Tungſten. Though this is not uſed it may be mentioned that with fluxes of phoſphoric acid it gives a blue glaſs, but not when borax or alkalies are uſed.

Of Chrome. This metal which is the natural colouring matter of the ruby and emerald, would be a moſt valuable ingredient for the artificial gems if it could be procured with tolerable eaſe. It has been found to give a fine red and alſo a moſt beautiful and exquiſite green to glaſſes, but its great ſcarcity has prevented its frequent uſe. (See *Chrome.*)

Having thus generally deſcribed the colouring properties of the ſeveral metallic oxyds, ſome of the actual recipes for the different coloured glaſſes may be mentioned. Theſe we ſhall chiefly give from M. Fontanieu, and from Neri and Kunckel, to which may be added the actual compoſition of a few of the beautiful antique coloured glaſſes, as found by the analyſis of Klaproth.[d] With regard to the recipes however, it may be added that there appears ſuch enormous difference in the relative proportions of the metallic oxyds to the fluxes uſed, as either to give a ſuſpicion of extreme inaccuracy or to ſhew that it muſt in moſt caſes be determined by individual experience.

Of the Ruby red, Purple, Violet, &c. by Gold. Little can be added here to what has been ſaid above under *Gold*. The particulars of the proceſs have always been carefully kept ſecret by the ſucceſsful artiſts, and from the frequent failures there can be no doubt that it is a very difficult proceſs to manage. According to Kunckel and others who have ſucceeded, it appears that the colouring power of the *purple precipitate of Caſſius*, or the mixed oxyds of gold and tin, is ſo great that one part will give a full rich body of colour to from 600 to 1000 or more of glaſs. The glaſs of antimony too ſeems an important addition. This ruby glaſs comes out of the fire colourleſs, but aſſumes its beautiful hue as it cools. It has been thought that the colour is alſo further brought out by expoſure to ſmoak.

Of other Reds, Purples, and Violets. Some of theſe are compoſed of a colourleſs glaſs baſis, ſuch as one of the five before mentioned, with manganeſe either alone or with the purple precipitate of gold, or more commonly with the oxyd of cobalt. The colour given by manganeſe being of a violet red, the cobalt will give it a more decided purple by adding its natural blue. It is impoſſible to pick out from the various recipes any other proportions than that the oxyd of manganeſe will colour very fully about 100 times its weight of glaſs when uſed alone, and when employed with cobalt, 200 parts of glaſs will be highly coloured with 1 of manganeſe, and (for a purple) about $\frac{1}{3}$ to $\frac{1}{4}$ of zaffre.

Neri gives the following receipt for a glaſs to imitate the garnet, namely, 2 oz. of rock cryſtal, 6 oz. of minium, 16 grains of manganeſe, and 2 grs. of zaffre. Kunckel gives for a violet red glaſs a common lead-glaſs baſis with $\frac{1}{12\frac{1}{2}}$ of manganeſe, mixed with nitre. Fontanieu gives for the imitation of the amethyſt, 24 oz. of his glaſs, No. 5 (as already deſcribed), $\frac{1}{2}$ oz. of manganeſe, and 4 grains of purple precipitate of gold, together with $1\frac{1}{4}$ ounce of nitre. But the quantity of colouring matter here is ſo enormous that the vitreous baſis ſhould probably be 24 *pounds* inſtead of *ounces*.

A fine red has been mentioned to be procured from the oxyd of copper (with or without oxyd of iron) mixed with the due proportion of glaſs and with carbonaceous matter ſtirred in. For a full deep red the oxyd of iron ſhould be three or four times as much as the copper, and in proportion as the latter predominates the colour approaches to carmine. The glaſs at firſt ſhould appear when hot only of a faint greeniſh-yellow, and, when in full fuſion, ſome tartar is ſtirred in, which inſtantly reddens the whole and cauſes it to ſwell prodigiouſly, after which it again ſubſides into a clear red glaſs, which ſhould be worked off without delay. Probably charcoal would anſwer as well as tartar.

The antique red glaſs analyzed by Klaproth muſt probably have been made in the ſame way,

[c] Eſſays, vol. 1.

[d] Phil. Journ. vol. 8.

that is by carbonizing a glaſs containing the oxyds of iron and copper. The colour was a lively copper-red, perfectly opake and bright at the point of fracture. The earthy and metallic parts of 400 grains, as given by analyſis, were as follows:

Silex - - - - -	142
Oxyd of lead - -	28
Oxyd of copper - -	15
Oxyd of iron - -	2
Alumine - - - -	5
Lime - - - - -	3
	195

It is obſervable that this was opake, whereas the former mentioned glaſs is tranſparent. Klaproth conjectures that this antique glaſs was made not by any intentional proportion or ſelection of ingredients, but from the ſcoriæ of ſome copper ores.

Of Green Glaſſes. For theſe, which are intended to imitate the emerald when full-bodied, and the aqua-marine when light, there are many receipts.

Among others the following may be ſelected. Take 160 parts of any glaſs baſis into which much lead enters, as the glaſs No. 1, 2, 3, or 5, mix it with 4 parts of the oxyd of copper made by ſimple calcination, and $\frac{1}{10}$ of a part of any oxyd of iron, and melt with a ſufficient heat. In this as in all the other emerald colours a very ſmall addition of iron ſeems highly uſeful to give ſomewhat of a richneſs of tint, and to take away the cold hue of the copper alone. For this reaſon too the rich yellow of the lead is of ſo much advantage.

Another is, 576 parts of the glaſs baſis, 6 of the ſame oxyd of copper, and only $\frac{1}{144}$ of oxyd of iron. Another is, 200 parts of fine ſand, 400 of minium, 8 of calcined verdigris, and 1 of oxyd of iron. The variation in theſe proportions is extreme.

Another method of compoſing the emerald-green is by a mixture of blue and yellow glaſs in due proportions. The yellow may be given by the oxyd of antimony, and the blue by cobalt. Fontanieu gives for this 120 parts of any of the glaſs baſes, 1 of *mountain blue*, and $\frac{1}{12}$ of glaſs of antimony: or elſe 576 parts of the glaſs No. 2, 20 of glaſs of antimony, and 3 of oxyd of cobalt (not zaffre).

When the green has a ſenſible mixture of blue in the tint it forms a fine ſomewhat cold colour reſembling the aqua-marine. This is produced in general by adding cobalt in ſome form or other to the materials for the green glaſs. For this the following receipts are given by Neri, Kunckel, and Fontanieu. Melt 300 parts of any fine cryſtal glaſs made without manganeſe, add thereto at intervals 6 parts of calcined copper or any ſimilar preparation, and $\frac{1}{4}$ of a part of zaffre, ſtir the glaſs well while mixing, and then let them fuſe quietly for ſome hours. No reaſons appear however why the whole materials ſhould not be mixed at firſt as in the uſual mode. Another is, 300 parts of fine ſoda glaſs with 6 of calcined braſs, melted together, ſtirred twice at long intervals, the heat being continued a long time, and finally ſuffered to remain in quiet fuſion for many hours before working. Another is, 256 parts of fine glaſs, and 150 of litharge or minium, firſt melted together and well mixed (or elſe any of the glaſs baſes already mentioned that contain lead), to which is added 4 parts of calcined braſs or of oxyd of copper made by calcination, and $\frac{1}{2}$ a part of zaffre. Another receipt for this colour is a mixture of yellow and blue, in ſuch proportions that the blue ſhall prevail a little over the perfect green, the natural reſult of the mixture of blue and yellow. This is done by adding to 24 parts of the glaſs baſis No. 1 or No. 3, $1\frac{1}{2}$ part of glaſs of antimony, and $\frac{1}{18}$ of a part of oxyd of cobalt.

According to Klaproth's analyſis of a portion of an antique verdigris-green opake glaſs, the colour was formerly, as now, given by copper and a ſmall portion of iron, the ſame in kind as thoſe that compoſed the red glaſs above mentioned, and probably alſo the oxyds were not artificially mixed but were uſed as contained in a natural ore. Two hundred grains of this green glaſs or paſte yielded

	grains
Of Silex - - - -	130
Oxyd of copper -	20
Oxyd of lead -	15
Oxyd of iron -	7
Lime - - - -	13
Alumine - - -	11
	196

Of Blue Glaſſes. Theſe glaſſes, which are intended to imitate the ſapphire, are compoſed of a common baſis and coloured with cobalt, but generally with the addition of a quantity of manganeſe, which by adding a violet tint gives a greater richneſs of body. When the manganeſe is in large proportion, the colour then is a rich violet blue or purple reſembling the ame-

thyſt. There appears no agreement in the different receipts as to the relative proportions of manganeſe, only that the latter ſhould be in leſs quantity than the cobalt when uſed in the dilute form of zaffre. Theſe mixtures appear to be materially improved by being twice melted and poured into water and powdered between the firſt and ſecond fuſion. Among the ſeveral receipts the following may be given, namely, to 100 parts of a fine glaſs, without lead, add 1 part of zaffre and $\frac{1}{16}$ of a part of manganeſe. Another is 240 parts of glaſs frit, made with ſoda and ſand only, 192 of minium, 2 of zaffre and $\frac{1}{3}$ of manganeſe melted twice and treated as above. Or a very fine blue glaſs may be made ſimply by the glaſs No. 5, with a neceſſary doſe of oxyd of cobalt or zaffre.

Though blue glaſſes cannot be now made without cobalt, it is certain that iron in ſome mode of combination gives this colour in great perfection. It appears to be the natural colouring matter of the ſapphire, lapis lazuli, and ſome other blue minerals, and is frequently produced accidentally in the ſcoriæ of iron ores. The art of colouring paſtes and enamels blue with iron was certainly known to the antients but is now entirely loſt. This is proved by the analyſis of ſome of the antient blue enamels, in which no metallic matter but iron, with a ſmall proportion of copper, can be detected. Whether the copper aſſiſts in the effect cannot be told. Klaproth analyzed an opake antient Roman enamel, the colour of which was ſapphire blue verging towards that of ſmalt, and found the following ingredients.

	parts
Silex	163
Oxyd of iron	19
Oxyd of copper	1
Alumine	3
Lime	0.5
	186.5

Some of theſe plates of enamel were coloured equally throughout, others only to a certain depth on one ſurface, and the colour was given ſo uniformly that the plate had the appearance of two plates, one blue and the other colourleſs, adhering to each other.

Of yellow Glaſſes. The oxyds of lead, antimony, and ſilver are thoſe which are uſed to give a yellow to imitate the varieties of the topaz, or the yellow diamond. M. Fontanieu gives the following proportions: 24 parts of the glaſs *No.* 1, or *No.* 3, and $\frac{1}{8}$ of a part of glaſs of antimony, or for the deeper coloured topaz, $\frac{6}{8}$. For the imitation of the Brazilian Topaz he adviſes 192 parts of the glaſs *No.* 2, or *No.* 3, $8\frac{1}{3}$ parts of glaſs of antimony, and $\frac{1}{3}$ of a part of the purple precipitate of gold. An inferior yellow glaſs may be made by fuſing ſimply 2 parts of fine ſand or ſilex of any kind, with 7 parts of minium, but this is very ſoft. The delicate hue of the yellow diamond is imitated by adding to 576 parts of the glaſs *No.* 4, 25 parts of luna cornea, or ten parts of glaſs of antimony.

A colour varying in ſhade from brown to dingy ſmoke yellow, and thence to a fine tranſparent yellow, is given to common glaſs ſimply by adding to it when in ſoft fuſion, any vegetable carbonaceous matter, part of which riſes to the top and is burnt off, but a part alſo remains uniformly diffuſed through the glaſs, and gives it a fine yellow without impairing its tranſparency. No continuance of the fire will burn out this yellow colour altogether, after it has once loſt its dingy ſmoked hue and acquired a clear yellow. Tartar has been commonly uſed for this purpoſe, but almoſt any vegetable inflammable ſubſtance not fluid, will probably do as well; the ſoft charcoal of the beech anſwers the ſame purpoſe. Manganeſe has been employed in the compoſition of this glaſs, but it appears to be of no uſe.[a] Sometimes the carbonaceous matter is added to the glaſs frit when beginning to melt in the glaſs pots, at other times it is mixed with it before firing. A little nitre is found of uſe in clearing the colour and correcting the ſmoakineſs, but too much of it will deſtroy the colour altogether. This glaſs ſwells much in the pot, when preparing, owing to the eſcape of part of the carbonaceous matter, eſpecially when tartar is employed: but probably with quite dry and freſh burnt charcoal, previouſly heated ſtrongly in cloſe veſſels for about an hour, no ſuch effect would take place.

Of the Artificial Diamond. Though no art has ever invented any vitreous compoſition which can be miſtaken for the real cut diamond, by an eye at all practiſed, (unleſs by particular artifices in the ſetting, which are eaſily detected) yet ſome artiſts can prepare a very fine brilliant hard glaſs paſte, which poſſeſſes great beauty, and a very conſiderable *water* or play of light, which more nearly imitates the diamond than all the common artificial gems. It will be ſufficient here to add that M. Fontanieu recommends his glaſs *No.* 1, for this purpoſe. Theſe glaſſes require a conſiderable length of time of ſtrong fuſion before they are

[a] Lewis Commerce of Arts, p. 628.

brought to the ſtate of the greateſt clearneſs and brilliance.

Of Opake Glaſſes.

The materials which form the opake glaſſes are a common vitreous baſis, as for the coloured glaſſes, and either an exceſſive doſe of colouring metallic oxyd which ſhall give ſuch a depth and body of colour as to produce opacity, or a ſubſtance which of itſelf gives an opake whiteneſs, to which any colour may be afterwards added if required. In general it is only the black glaſſes which are made opake by mere quantity of the ſame colour which, in ſmaller proportion, would be tranſparent; and the white glaſſes are made with a glaſs rendered opake by ſome addition which in any proportion impairs the tranſparency; and the blue, green, yellow, and other coloured opake glaſſes have the white glaſs for a baſis, and are coloured in the ſame way as the tranſparent glaſſes.

White Glaſs. The fineſt white glaſs is a vitreous baſe made opake by the oxyd of tin, and is then called *Enamel*, (which ſee).

But a very good white may be made at leſs expence by ſubſtituting for the oxyd of tin a pretty large quantity of bone-aſh or phoſphat of lime in very fine powder. It appears to be owing chiefly to the extreme infuſibility of this earthy ſalt that the opacity is produced, ſo that in fact the glaſs thus made is a common vitreſcent compound holding in intimate mixture a quantity of unvitreſcible earth.

Neri's receipts for white glaſs are the following: mix together 60 parts of white ſand, 40 of potaſh, and 10 of finely powdered bone-aſh, and melt for the uſual time of glaſs-making. The reſult is a glaſs which when fully red-hot is tranſparent, but becomes milky and opake as ſoon as it cools. It does not appear certain whether this change is chiefly owing to a deception of ſight which does not allow the degree of opacity to be diſtinguiſhed when red hot, or whether the glaſs really becomes opake only when it cools, and then depoſits the bone-aſh by the effect of a kind of ſuperſaturation by heat.

Another receipt is, 130 parts of ſand or calcined flint, 70 of nitre, 12 of borax, 12 of tartar, 5 of arſenic, and 15 of bone-aſh.

An imitation of the opal is made according to Fontanieu by mixing 576 parts of the glaſs *No.* 3, 10 of luna cornea, 2 of magnetic iron ore, and 26 of bone-aſh.

Black Glaſs. It is not eaſy to make a very full-bodied, perfectly opake, fine black glaſs. This is commonly made by manganeſe, and it has been found that one part of this oxyd will give a full body of opake black to about 20 of glaſs. A finer black uſed chiefly by the enamellers is made (as appears) by mixing together equal parts of manganeſe, zaffre, and ſcales of iron, and fuſing one part of this mixed powder with 15 or twenty of any kind of glaſs.

For the other opake coloured glaſſes no more need be added than that they may be made in the ſame way as the tranſparent coloured glaſſes, ſubſtituting the opake white glaſs for the common vitreous baſe. Theſe however are not much uſed in maſs, or for any of the common uſeful or ornamental purpoſes to which the tranſparent glaſſes are applied. The opake coloured enamels are compoſed on the ſame general principles, the baſe being the white enamel made with the oxyd of tin.

GLASS OF BORAX is borax calcined till it loſes its water of cryſtallization and flows into a very thin limpid glaſs. A moderate red heat is ſufficient for the purpoſe. This becomes ſlightly opake by expoſure to the air, in conſequence of an incipient efflorescence.

GLASS-GALL, or *Sandiver*, is the ſcum of the glaſs-pots which ariſes during the vitrification of the frit. See GLASS.

GLASSES *(Metallic)*, are the oxyds, or ſometimes the ſulphuretted oxyds of the different metals vitrified by heat. Thoſe of lead and antimony are the moſt familiar to Chemiſts. *(See the reſpective metals.)*

GLAS SCHORL. See THUMERSTEIN.

GLAUBER'S SALT. See SULPHAT OF SODA.

GLAUBER'S SALT,[a] native. *Naturliches Glauberſalz, Germ.*

Its colour is greyiſh or yellowiſh-white. It occurs generally efflorescent or incruſting, rarely ſtalactitical, and ſometimes in minute acicular or middle-ſized priſmatic cryſtals. Internally the cryſtals are ſhining, with a vitreous luſtre, but by a ſhort expoſure to the air they become dull and efflorescent. Its fracture when cryſtallized is conchoidal, when amorphous is earthy. It varies from tranſparent to opake, according as it is more or leſs in a ſtate of efflorescence. It is brittle and eaſily frangible, has a bitter ſaline taſte, and is readily ſoluble in water. It gives a copious precipitate with barytic ſalts, but is not altered by carbonated potaſh. When fully ſaturated with water of cryſtallization it contains according to Bergman,

Sulphuric acid	27
Soda - - -	15
Water - - -	58
	100

[a] Brochant. Jameſon.

The native Glauber's ſalt however, eſpecially when effloreſcent, contains beſides pure ſulphat of ſoda, ſome oxyd of iron, accidental earthy impurities, and more or leſs of muriat and carbonat of ſoda. It is met with in old ſalt-mines, on the borders of ſalt-lakes in Hungary, Tartary, and Egypt, and on the ſurface of certain peat moſſes eſpecially in the north of France. It is contained in ſolution in the Natron-lakes of Egypt, and the mineral ſprings of Carlſbad.[b]

GLIMMER. See MICA.

GLIMMERSCHIEFER. See MICACEOUS SCHISTUS.

GLUE. See GELATIN.

GLUTEN, *(Animal.)* See FIBRIN, and BLOOD.

GLUTEN, *vegetable.* A ſubſtance very cloſely reſembling animal gluten in all the eſſential chemical properties, is found in ſeveral vegetables, and hence it has received the name of vegetable gluten.

Wheat flour was firſt found by Beccari to contain it in conſiderable quantity, and it is from this ſource that it is uſually obtained for experiment by the following ſimple and eaſy proceſs.

Moiſten any quantity of wheat flour with a little water, and knead it with the hand into a tough ductile paſte, then let a very ſlender ſtream of water keep dropping on the paſte while it is inceſſantly worked about with the hands, and the water will run off white and turbid, owing to the fecula or ſtarch which it carries off. The paſte in the mean time gradually becomes more of a grey and almoſt ſemitranſparent appearance, and when the water runs off quite clear, nothing is left in the hands but pure gluten. No other precaution is required in this preparation but that of not drenching the flour at firſt with water, but only uſing a very ſmall quantity with much kneading, that the gluten may not be carried off along with the ſtarch. Good wheat flour will yield in this way about a fourth of its weight of gluten, and no other flour but that of wheat will yield it except in a very ſmall proportion, and hence probably the peculiar property of wheat flour to make bread without any other addition than a ferment. See the article BREAD.

Gluten thus prepared is ſoft, extremely tenacious and elaſtic, ſo as to bear being extended conſiderably without pulling in pieces, and returning to its former dimenſions. It is alſo conſiderably adheſive, readily ſticking to the fingers. Its colour is a dirty grey, and it has a faint and peculiar ſmell. It readily dries into a brittle ſemitranſparent ſubſtance, which looks not unlike glue, and in drying, it ſtrongly adheres to the ſubſtance on which it reſts: ſo that advantage is taken of this property to cement together broken pieces of china and other rough ſurfaces.

Gluten is abſolutely inſoluble in water, though it muſt owe its adheſiveneſs and ductility to the water which it abſorbs when the flour is firſt wetted. Boiled with water it only becomes denſer, and loſes part of its adheſiveneſs. All the acids, vegetable as well as mineral, the latter being diluted, diſſolve it without difficulty, forming a clear ſolution, from which it is again ſeparated by alkalies. Strong ſulphuric acid blackens and carbonizes it, and diſengages from it an inflammable gas, and converts it partly to acetous acid, partly to ammonia. Concentrated nitric acid when cold diſengages azotic gas from it, when hot it converts it chiefly into malic and oxalic acids with evolution of much nitrous gas and ammonia.[a]

The alkalies alſo diſſolve gluten with eaſe.

When gradually heated without addition, it dries thoroughly, then ſhrinks and coils up like moſt other of the ſoft animal ſubſtances, then melts and takes fire, burning with the fetid odour of animal matter.

In cloſe veſſels it yields ſome ammoniacal water, and a very brown fetid thick oil in abundance, together with cryſtallized carbonat of ammonia and carburetted hydrogen.

In ſhort, it exhibits to chemical analyſis all the properties of animal matter.

Gluten, when dry and kept ſo, remains unaltered for any length of time, but if kept conſtantly moiſt in the ſtate in which it was firſt procured, it ſlowly alters, loſes much of its tenacity, becomes fetid and covered with a thick white down, and falls into putrefaction. This proceſs however is ſlow, and at the ſame time a ſour ſmell is perceivable, and an acid is generated which probably corrects and retards the proper putrefaction. In this circumſtance it is that it chiefly differs from animal gluten.

M. Cadet[a] has found that gluten after being kept for many days moiſt and mouldy is partially ſoluble in alcohol. Some of this gluten was rubbed up with alcohol and paſſed to the ſtate of a thick turbid ſyrup; on adding more of the ſpirit much of the gluten ſeparated in its original form, but a part remained in perfect ſolution. This latter being diluted with water immediately became milky, and let fall a copious white pre-

[b] Klapr. analy. Eſs. I. p. 296. II p. 60.

[a] An. Chim. tom. 41.

cipitate which appeared like a fecula, but was gluten in intimate diviſion. Another part of the alcoholic ſolution being gently evaporated left behind a dry, brittle, yelloviſh, gloſſy gluten, appearing like a varniſh, and which the author of the experiment propoſes to be uſed for this purpoſe, either by itſelf, or as a vehicle for colours of different kinds.

Gluten is contained in ſmall quantity in ſeveral vegetable juices and other parts, and may be ſeparated from them with care: though in none is it ſo abundant as in wheat flour. Bird-lime, a ſingular ſubſtance extracted from the bark of the holly and alſo from the miſletoe, is ſuppoſed to be chiefly gluten, and the green FECULA of plants alſo appears to be compoſed very largely of this ſubſtance, as mentioned under that article.

GLYCINE. *Glucine.* Fr. The diſcovery of this earth is due to Vauquelin,[a] who firſt found it in the beryl and afterwards in the emerald: the exiſtence of a new earth in theſe minerals has ſince been confirmed by the reſearches of Klaproth[b], ſo that the exiſtence of glycine as a peculiar earth may be conſidered as eſtabliſhed very ſatisfactorily. Its name is derived from the greek γλυκυς (ſweet) on account of the remarkably ſaccharine taſte by which its ſalts are diſtinguiſhed. This however although a ſtriking character at the time when the earth was firſt diſcovered has ſince ceaſed to be a ſpecific diſtinction as it is poſſeſſed both by glycine and the ſtill more recently diſcovered earth called Yttria, (ſee p. 455.)

In order to procure glycine in a perfectly pure ſtate, take any quantity of beryl or emerald, and having reduced it to very fine powder, mix it with about three times its weight of cauſtic potaſh in a liquid form, and digeſt it to dryneſs in a ſilver crucible, after which let it be moderately ignited for about half an hour: the reſulting maſs will be found to be entirely ſoluble in a ſlight exceſs of muriatic acid, and the ſolution after being evaporated to dryneſs and then diffuſed in water, will depoſit nearly the whole of the ſilex. The muriatic ſolution is now to be ſuperſaturated with cauſtic potaſh or ſoda and boiled, by which the oxyd of iron and of chrome, if any is preſent, will be ſeparated. The clear liquor being again ſuperſaturated with muriatic acid and afterwards mixed at a boiling temperature with carbonat of ſoda, depoſits the whole of its earthy contents in the form of a white ſoft precipitate: this when well waſhed in water, is to be diſſolved in ſulphuric acid, and the ſolution being transferred to a ground ſtoppered bottle is to be conſiderably ſuperſaturated with carbonat of ammonia: both the alumine and glycine will be at firſt precipitated, but this laſt, by the aſſiſtance of occaſional agitation will be rediſſolved in the courſe of a few hours. The clear liquor being poured off, the earthy reſidue is to be again diſſolved in ſulphuric acid, and ſulphat of potaſh being added, a copious depoſit of cryſtals of alum will take place: the mother liquor and waſhings of the cryſtals being again treated with a large exceſs of carbonated ammonia, the remaining portions of glycine will be extracted, and the two ammoniacal ſolutions are to be added together. This fluid when boiled in a retort will depoſit the whole of the glycine in the ſtate of a white powder, and combined with carbonic acid: after being waſhed and dried it muſt be ignited, by which it will loſe carbonic acid and moiſture to the amount of about half its weight, and the reſidue is pure glycine.

Glycine is a white powder, ſoft and ſomewhat unctuous to the touch, adheres ſtrongly to the tongue, is inſipid and inodorous. It produces no change on vegetable colours, and therefore does not belong to the claſs of alkaline earths. It does not contract in its dimenſions by heat, nor is it fuſible: but with the aſſiſtance of borax it runs into a clear tranſparent glaſs. Its ſp. gr. is 2.96. It is not ſoluble in water, but when moiſtened with this fluid it forms a ſomewhat ductile paſte. It combines with ſulphuretted hydrogen through the medium of water. It is ſoluble in the liquid fixed alkalies, reſembling in this reſpect alumine. It is inſoluble in ammonia, but diſſolves readily in carbonated ammonia as yttria does, except that this latter requires for its ſolution five times as much of this menſtruum as glycine does.

It unites with the acids forming ſaline compounds, all the ſoluble ones of which have a remarkably ſweet ſubaſtringent taſte.

Carbonat of Glycine may be prepared either by precipitating ſulphat of glycine by either of the carbonated fixed alkalies, or ſimply by heating the ſolution of glycine in carbonated ammonia: a white impalpable powder falls down, which is carbonat of glycine.

This ſalt according to Klaproth conſiſts of

Glycine - - - - -	53
Carbonic acid and water	47
	100

[a] An. de Chim. xxvi. p. 170.

[b] Analyt. Eſs. II. p. 172-176.

It is decompoſable by a low red heat, the acid and moiſture being driven off: it is alſo decompoſable with efferveſcence by the other acids.

Phoſphat of Glycine is obtained by adding phoſphat of ſoda, to ſulphat, nitrat, or muriat of glycine: a white pulverulent precipitate falls down, which is the ſalt in queſtion. When perfectly neutralized it is uncryſtallizable, inſoluble in water, and inſipid: at a high heat it melts into a tranſparent glaſs: when the acid is in exceſs it is ſoluble in water. It is decompoſable by the alkaline carbonat and alkaline earths, except carbonat of magneſia, and by the ſulphat, nitrat, and muriat of alumine.

Sulphat of Glycine is procured by adding either pure or carbonated glycine to ſulphuric acid till this laſt is perfectly ſaturated: by ſpontaneous cryſtallization, ſulphat of glycine is depoſited in octohedrons compoſed of two oblique four-ſided pyramids joined baſe to baſe, with the edges and ſolid angles truncated. The taſte of this ſalt is very ſweet, and ſomewhat aſtringent: it is readily ſoluble in water, and tincture of galls added to the ſolution occaſions a yellowiſh white precipitate. The ſolid ſalt when heated diſſolves in its water of cryſtallization, and afterwards becomes pulverulent: at a red heat the acid is entirely driven off, the pure earth being left behind.

If a little ſulphat of potaſh is added to a ſolution of ſulphated glycine, and the liquor is ſlowly evaporated, a quantity of ſmall cryſtalline grains are depoſited which are readily ſoluble in ſeven or eight times their weight of cold water. If carbonated glycine is digeſted in a ſolution of common alum, the glycine is taken up and the alumine entirely precipitated.

Nitrat of Glycine is prepared in the ſame manner as the preceding ſalt, by ſubſtituting the nitric for the ſulphuric acid. Its taſte is ſweet and aſtringent, it is ſtrongly deliqueſcent, and when evaporated aſſumes the conſiſtence of honey, but does not cryſtallize: like the preceding ſalts it is decompoſable by a red heat the acid being evaporated. With tincture of galls it gives a yellowiſh brown precipitate.

Muriat of Glycine both in the mode of its preparation and in its general characters bears a cloſe reſemblance to the preceding, it is however capable of being cryſtallized, which is not the caſe with nitrat of glycine.

Neither the pure earth nor any of its ſalts have been applied to any uſe.

GNEISS.[a] Gneiſs is eſſentially an aggregate of quartz, felſpar and mica: of theſe ſubſtances the latter is in the form of extremely thin plates, all of which are arranged in the ſame direction and parallel to the general inclination of the ſtratum. In its compoſition, gneiſs is the ſame as granite, but differs in the arrangement of its parts, eſpecially of the mica, which in granite is diſperſed throughout its ſubſtance in every direction; gneiſs has a flaty texture and ſplits readily in the direction of the mica, hence from its longitudinal fracture it would be ſuppoſed to conſiſt almoſt wholly of this ſubſtance, while from its croſs fracture it ſeems made up of quartz and felſpar interrupted by very narrow lines of mica.

There are three varieties of gneiſs. In the firſt each ingredient forms a diſtinct ſtratum irregularly alternating with the others and repreſenting on its croſs fracture parallel bands of quartz, felſpar, and mica, either even or undulating. This variety forms the connecting link between granite and common gneiſs, the undulatingly banded, paſſing immediately into the latter, and the even banded, which may without impropriety be named banded granite, *granite veiné of Sauſſure*, into the former. The ſecond variety is common gneiſs: in this the ingredients are more mingled than in the preceding, and its fracture is coarſely flaty. When the component parts are ſtill more intimately mixed, the maſs belongs to the third variety or foliated gneiſs: the fracture of this is fine flaty paſſing into foliated, and the mica ſeems to prevail, if not in quantity at leaſt in efficacy over the quartz and felſpar, the characters of which are obſcured by thoſe of the mica: when the mica is very predominant, the rock paſſes into micaceous ſchiſtus.

The quartz in gneiſs is generally of a whitiſh or ſmoak grey colour, and it is either opake or ſlightly tranſparent. The felſpar in thoſe ſpecimens that paſs into granite is moſtly fleſh-red, in the others it is greyiſh or yellowiſh white. The mica is ſilvery white or tombac brown verging upon black. It ſometimes though rarely happens that the felſpar is in a ſtate of decompoſition approaching to porcelain clay, whence ſome authors have mentioned indurated clay as a component part of gneiſs.

Among the ſubſtances accidentally incloſed in gneiſs may be reckoned garnet, which very frequently, and ſchorl which very rarely occurs, alſo fragments of granite, hornblende, and occaſionally ſteatite. Gneiſs is one of the primitive rocks, and in its formation is conſidered as immediately poſterior to granite, as it is uſually

[a] Lenz. Brochant.

found to reſt upon this: it is diſtinctly ſtratified, and between the ſtrata are ſometimes interpoſed beds of granular limeſtone, hornblende ſlate, common actynolite, quartz, and rarely porphyry. This rock is remarkably rich in metallic ores both in ſtrata and veins: it contains gold, native ſilver, red and white ſilver ore, tin ſtone, galena, martial, arſenical, and copper pyrites, blende, arſenical cobalt, &c. accompanied by brown ſpar, heavy ſpar, fluor ſpar, calcareous ſpar, quartz, clay porphyry, wackke, hornſtone and jaſper. Moſt of the Saxon and Bohemian mines are in gneiſs, as alſo are the ſilver mines of Kongſberg in Norway.

Gneiſs although a common rock, is by no means of ſo frequent occurrence as granite.

GOLD. *Gold*, Germ. *Aurum*, Lat. *Or*, Fr. *Sol*, Alchem.

Gold is a metallic ſubſtance of a pure yellow colour, remarkably ductile and malleable, of great ſpecific gravity, and nearly as ſoft as tin. In fuſibility it ranks between ſilver and copper; it is not oxydable by fuſion in atmoſpheric air; nor is it acted on by any of the acids except the oxymuriatic and nitro-muriatic (aqua-regia.)

§ 1. *Ores of Gold.* [a]

Gold is found only in one ſtate, namely, the reguline, but is hardly ever pure, being alloyed more or leſs by ſilver, copper, tellurium, and a few other metals. When alloyed with ſilver or copper, or with both, it preſerves its ductility, and is reckoned as native gold; when combined with tellurium it entirely loſes its diſcriminative external characters, and in this ſtate is generally claſſed among the ores of tellurium. For the convenience however of the reader, we ſhall deſcribe this latter ſubſtance both here and when we come to treat of tellurium, truſting that a little repetition will be excuſed on this account.

1 Sp. Native Gold. *Gediegen Gold.* Wern. *Or Natif.* Broch. and Hauy.

Its colour when pure or nearly ſo, is a bright, ſomewhat orange yellow; in proportion as it is alloyed with ſilver it inclines to a pale braſs yellow; when combined as is ſuppoſed with platina, it paſſes from braſs-yellow to ſteel-grey. It occurs in detached lumps and grains, diſſeminated, ſuperficial, reticulated, dendritical, capillary, cellular and ſcaly, as a ſnuff-coloured powder, and ſometimes, though rarely, cryſtallized in ſmall cubes, regular octohedrons and rhomboidal dodecahedrons. The cryſtals are for the moſt part minute and very irregular. The ſurface of the cryſtals is ſmooth and brilliant; of the other varieties the luſtre is faintly ſhining and glimmering; when cut with a knife it diſplays a bright and perfectly metallic luſtre. Its fracture is hackly. It is very ſoft, perfectly ductile and flexible, but not elaſtic. Its ſpecific gravity varies according to its purity from about 17. to 19.

Before the blow-pipe it runs into a globule without emitting any vapour.

Native gold is rather a rare mineral, and is by no means the principal ſource of this valuable metal. It occurs in veins or diſperſed through the ſubſtance of primitive mountains, eſpecially argillaceous ſchiſtus, and clay porphyry, and is accompanied by quartz, felſpar, calcareous and heavy ſpars, pyrites, red and vitreous ſilver ore, galena, &c. The richeſt mines of native gold are found in Brazil, Peru, and Mexico; ſome of the African, Sumatran, and Japaneſe gold, is alſo procured from a ſimilar ſource; the mine of Bereſof in the Uralian mountains, and ſome of the Hungarian and Tranſylvanian mines likewiſe yield native gold, though in ſmall quantities.

But by far the largeſt proportion of native gold is found accidentally diſperſed through certain alluvial ſtrata. That this is not its natural ſituation is manifeſt from its occurring here only in rounded and flattened maſſes, from microſcopical ſpangles to pieces three or four pounds in weight, all of which exhibit decidedly the effects of friction. It is from the ſands of certain rivers that this ſtream gold as it may be called, has been chiefly procured; and it was naturally thought that its original bed was at the mountainous ſources of theſe ſtreams, whence it was detached by the force of the torrents, and depoſited in the lower and quieter part of the river. In ſome inſtances this is no doubt the caſe, but in moſt others the tranſportation of the gold appears to have taken place at a period anterior to the formation of our preſent rivers. Where gold is found in the bed of an actual torrent at no great diſtance from its ſource and in a mountainous country; where too the gold is confined within the preſent or probable former boundaries of the ſtream (as is particularly the caſe with that recently found near Cronebane in the County of Wicklow in Ireland) it may be conſidered as indicating the preſence of gold, either diſperſed or in a regular mine in the adjoining rocks. But on the other hand, when gold is found in the bed of a river at a conſiderable diſtance from its ſource; if the ſurrounding country is plain

[a] Hauy, Brochant, Jameſon.

or nearly ſo; if the auriferous ſand forms a ſtratum extending to a conſiderable diſtance beyond the river; then it is probable that the river has merely cut through a previous alluvial ſtratum holding gold, and that to endeavour to find the mine whence this metal originated by ſearching the rocks towards the ſource of the ſtream, is mere loſs of time.

A conſiderable portion of the ſtream gold ſeems to have been contained in auriferous pyrites, for almoſt all the ſands from which this metal is extracted are highly ferruginous, and of a deep blackiſh-brown colour: the gold itſelf is moſtly of a pale yellow, and is conſiderably alloyed with ſilver. The Peruvian, Mexican, and Brazilian rivers, are many of them extremely rich in gold, as are likewiſe ſeveral of the ſtreams on the Weſtern coaſt of Africa: in Europe, the Danube, the Rhine and the Rhone, afford ſmall quantities of this metal, and from ſeveral other of the leſſer rivers it has been extracted rather for curioſity than profit: the ſtreams of Hungary and Tranſylvania, under the patient management of the Zigeuners or Gipſeys, yield a greater quantity of gold than the reſt of the European rivers, yet hardly ſufficient to afford a very ſcanty maintenance to the labourers. [b] Of the alluvial ſtrata yielding gold, none has ever been found comparable in richneſs to the plain of Cineguilla in the province of Sonora, on the Eaſtern ſhore of the Californian gulf: this plain is about fourteen leagues in extent, and contains large lumps of gold irregularly diſperſed through it at the depth of about 14 inches.

Sp. 2. Graphic Gold. *Schrifterz.* Wern. *Silvane graphique.* Broch. *Aurum graphicum. White Gold Ore of Offenbanya*, of the older mineralogiſts.

Its colour is tin-white with a ſhade of braſs-yellow: it occurs cryſtallized in ſmall flattened priſms with four or ſix ſides, and terminated by tetrahedral pyramids; the cryſtals are diſpoſed in rows, and either parallel or at right angles to each other, giving the whole a ſort of reſemblance to writing (whence the name of this mineral). The cryſtals are ſmooth, and exhibit a bright metallic luſtre: the fracture is fine-grained uneven. It is ſoft, brittle, may eaſily be cut with a knife. Sp. gr. 5.7.

When expoſed to the blow-pipe it burns with a green flame, and a copious ſomewhat acrid vapour, leaving behind a malleable metallic globule. According to the analyſis of Klaproth, it conſiſts of

Tellurium -	60
Gold - -	30
Silver - -	10
	100

It has hitherto been found only at Offenbanya in Tranſylvania, in thin layers, upon grey quartz, in clay porphyry, and is accompanied by iron-pyrites, grey-copper, blende, and occaſionally native gold.

Sp. 3. White Gold Ore. *Weiſs Silvanerz.* Wern. *Silvane blanc.* Broch. Yellow Gold Ore of Nagy-ag.

Its colour is ſilver-white paſſing into braſs-yellow: it occurs diſſeminated, and in ſmall imbedded priſmatic cryſtals. Externally it has a bright ſhining metallic luſtre. Its longitudinal fracture is foliated, the croſs fracture is ſmall-grained uneven. It is ſoft and ſomewhat ductile. Sp. gr. 10.6.

It conſiſts according to Klaproth of

Tellurium -	44.75
Gold - -	26.75
Lead - -	19.5
Silver - -	8.5
Sulphur -	0.5
	100.00

It has hitherto been found only at Nagy-ag in Tranſylvania, where it occurs in a gangue of quartz and brown ſpar, accompanied by blende, grey-copper, and copper-pyrites.

Sp. 4. Black Gold Ore. *Nagyagerez.* Wern. *Silvane lamelleux.* Broch.

Its colour varies from lead-grey to iron-black: it is ſeldom found in maſs, being generally diſſeminated in the form of ſmall ſcales, or long hexagonal plates, either ſingle or accumulated on each other. It has a moderately ſhining metallic luſtre. Its fracture is curved-foliated: it ſtains the fingers a little, is ſomewhat flexible, and very ſoft. Sp. gr. 8.9.

Before the blowpipe it readily enters into fuſion, and the tellurium and ſulphur are volatilized, leaving behind a metallic malleable globule ſurrounded by yelloviſh ſcoriæ.

It conſiſts according to Klaproth of

Tellurium - -	32.2
Lead - - -	54.
Gold - - -	9.
Silver - - -	0.5
Copper - -	1.3
Sulphur - -	3.
	100.0

[b] Born, Voyage Mineral.

It has been found as yet only at Nagy-ag in Tranſylvania, in a gangue of red manganeſe, brown ſpar, and quartz, accompanied by galena, iron pyrites, blende, plumoſe antimony and grey copper ore.

Sp. 5. Auriferous Pyrites.

The bronze-yellow IRON PYRITES in maſs or in ſtriated cubes, and the hepatic pyrites when occurring in veins in primitive mountains, are ſometimes found to contain a ſufficient quantity of pure gold, or of gold alloyed with ſilver, to be well worth the trouble of extracting by methods that will be deſcribed hereafter. It was formerly ſuppoſed that the gold as well as the iron in this ore, was mineralized by the ſulphur; the experiments of Bergman however pretty clearly ſhew that this is a miſtake, and that the gold in ſmall ſcales is merely interpoſed between the laminæ of the pyrites. A conſiderable proportion of the American gold, and by far the largeſt portion of the Hungarian gold, is obtained from this ore. The produce of the Hungarian pyrites is very various, ſometimes not exceeding a few grains of gold in the quintal of ore, but in the celebrated mine named Maria of Loretto, near Zalathna, in Tranſylvania, is a vein of auriferous pyrites, that occaſionally yields as much as 450 oz. of gold in the quintal. [c]

Sp. 6. Auriferous Galena.

The native Sulphuret of LEAD, commonly called galena, almoſt always contains a little ſilver, which not unfrequently is ſufficiently abundant to be worth the trouble of extracting.

The galena of Hungary occaſionally holds not only ſilver but gold, and is accordingly worked as one of the ores of this precious metal: the galena of Boicza yields an ounce and a half in the quintal of an alloy, of which 31 parts are ſilver and 1 of gold. [d]

§ 2. *Analyſis of Gold Ores.*

The analyſis of gold-ores is very ſimple, the chief difficulty ariſing from the minute proportion of this metal contained in the greater part even of thoſe ores which are reckoned very rich.

Native gold contains in variable but generally ſmall proportions either ſilver or copper, and ſometimes both; and its gangue is often quartz of extreme hardneſs. When this happens to be the caſe the following is generally the beſt mode of proceeding. After the ore has been reduced to fine powder let it be mixed with five or ſix times its weight of carbonated ſoda, or ſtill better with 4 parts of carbonated ſoda and 1 of glaſs of borax, and melted in an earthen crucible: the maſs when fuſed is to be poured out on a ſtone ſlab, and the ſmall portion remaining in the crucible may be readily detached by a little diluted muriatic acid. The whole maſs coarſely pulverized is to be put into a flaſk with this muriatic ſolution, and ſtrong muriatic acid being added a gentle warmth is to be applied; the digeſtion muſt be continued, a little nitrous acid being added from time to time, till the action of the menſtruum entirely ceaſes and the undiſſolved reſidue is of a pure white colour: the liquor is then to be poured off, the reſidue is to be well waſhed, and the waſhings added to the liquor.

a. The inſoluble reſidue being dried is to be expoſed to the ſun, and will acquire a purpliſh tint if it contains any muriat of ſilver. Upon this indication it is to be mixed with thrice its weight of pearlaſh and fuſed in an earthen crucible for about five minutes; the ſilver will be reduced into metallic globules, and may be obtained pure by digeſtion in muriatic acid, which will take up the earth and alkali but will not act on the ſilver.

b. The nitro-muriatic ſolution being carefully neutralized with either of the fixed alkalies, a ſolution of green ſulphat of iron is to be added as long as any precipitation takes place; this precipitate is gold, which being carefully collected is to be fuſed in a ſmall crucible with juſt a ſufficient quantity of nitre to cover it.

c. The reſidual liquor being decompoſed by a carbonated alkali, the precipitate after being well waſhed is to be digeſted in liquid ammonia to take up the copper, which being done, the ammoniacal ſolution is to be ſlightly ſuperſaturated with muriatic acid, and the addition of a ſtick of zinc will preſently throw down the copper in the reguline ſtate.

The ſecond, third, and fourth ſpecies of gold ore containing a large proportion of tellurium are to be analyſed in the following method. [e]

a. The ore being finely pulverized and ſeparated as accurately as poſſible from the lighter ſtony particles by waſhing, is to be digeſted with muriatic acid, to which muſt be added by degrees ſucceſſive portions of nitric acid, till the black colour of the ore has entirely diſappeared. The firſt ſolution being poured off, a freſh quantity of muriatic acid may be employed in order to render it certain that every thing ſoluble has been taken up. This being poured off and the reſidue well edulcorated with boiling water, all the three fluids are to be mixed together.

[c] Born, Voyage Mineral, p. 193. [d] Ibid p. 217. [e] Klapr. Analyt. Eſſ. II. p. 1.

b. The infoluble refidue confifts of quartz, and may alfo contain fulphur and muriated filver. The fulphur will be found collected into a mafs by itfelf, which being dried, weighed, and afterwards ignited and again weighed, the difference of weight will indicate the quantity of fulphur: what remains after ignition is to be treated with nitro-muriatic acid, the foluble portion added to the former folution, and the infoluble part added to the other refidue. The filver is collected by mixing four parts of pearlafh and one of glafs of borax with the refidue and fufing the whole, and afterwards feparating the globules of filver by means of muriatic acid, as already mentoined.

c. The nitro-muriatic folution (*a*) upon the addition of the edulcorating water will let fall a white precipitate, but by fubfequent heating and evaporation it will be redifolved, and inftead of it, if any lead is prefent, acicular cryftals will be depofited: the evaporation muft be perfevered in till thefe cryftals ceafe to be produced: being then collected, carefully rinced in a little muriatic acid and afterwards highly dried, they will be found to be pure muriat of lead.

d. The folution thus freed from the lead is to be diluted a little with water and then to be largely mixed with fpirit of wine as long as any precipitate falls down; a gentle warmth will compleat the feparation, and the precipitate edulcorated with alcohol is to be redifolved in muriatic acid, from which it may be feparated in the ftate of oxyd of tellurium by accurately faturating the liquor with cauftic foda, or in the metallic ftate in the form of black flocks by means of zinc.

e. The remaining fluid is to be freed from its alcohol by evaporation or diftillation, the concentrated folution is to be moderateiy diluted with water, and a folution of nitrat of mercury made in the cold is to be dropped in till the laft portions of the precipitate are white: the precipitate, which is of a brown colour, is to be collected, wafhed, and fufed with nitre, and yields a button of pure gold.

f. The liquor is now to be faturated with carbonated foda at a boiling temperature as long as any precipitate is thrown down: this being redifolved in warm muriatic acid, and again fuperfaturated with carbonat of ammonia, affords a precipitate containing iron and manganefe.

g. The ammoniacal folution being flightly fuperfaturated with muriatic acid will depofit all its copper in the metallic ftate by the action of a piece of zinc.

It is not known whether gold ever exifts native in a ftate of proper combination with platina, nor is there any extant analyfis of thofe ores in which platina is fimply mixed with grains of gold. The method of proceeding however in fuch cafes is fufficiently obvious by recollecting that though both the metals are foluble in aqua regia, yet gold alone is precipitable from this menftruum by the addition of fulphat of iron.

Auriferous pyrites is analyfed by digefting the pulverized ore in muriatic acid with the occafional addition of a little nitric acid till every thing foluble is taken up; the refidue being wafhed and dried is to be weighed and then expofed to a heat juft fufficient to burn off the fulphur, the amount of which is indicated by the lofs of weight. The refidue is again to be digefted in nitro-muriatic acid, and this folution is to be added to the firft. The earthy refidue containing the filver in the ftate of muriat is then to be fufed with an equal weight of glafs of borax and thrice as much pearlafh, the filver will be reduced and may be feparated from the alkali and earth by very dilute muriatic acid. The nitro-muriatic folution is to be neutralized by fixed alkali and then treated with nitrat of mercury prepared in the cold, by which the gold will be thrown down in the ftate of a brown powder, and may be brought to the reguline appearance by fufion with nitre. The oxyd of iron remains in folution and may be obtained in the ftate of magnetic oxyd in the ufual way.

Auriferous galena is to be treated nearly in the fame manner as the preceding. By the action of nitro-muriatic acid the gold and lead, as well as the iron and antimony, if any are prefent, are taken up, leaving behind the earthy matrix, the fulphur and filver, which are feparated as already mentioned in the former paragraph. The lead is depofited by gradual evaporation of the nitro-muriatic folution as cryftallized muriat of lead, and the gold is procured from the folution again diluted with water, by means of nitrat of mercury.

Where a mineral is examined merely for the gold and filver which it contains, it is a ufual practife to pulverize it very finely and digeft it firft in pure moderately ftrong nitric acid, and then in nitro-muriatic acid. In the firft folution is contained the filver, in the fecond the gold. This however is a very inaccurate way of proceeding, efpecially for the filver, becaufe whenever this does not greatly exceed the gold it will be more or lefs covered by it from the action of the nitric acid, and on the fubfequent

digeſtion with nitro-muriatic acid will be converted into muriat of ſilver and thus rendered inſoluble.

There are ſeveral ways mentioned by authors of analyſing in the dry way, or rather of aſſaying ores of gold: none of them however are equal in accuracy to the modes of analyſis by liquid menſtrua which we have already mentioned, and are in fact only a more careful performance upon ſmall quantities of materials of thoſe proceſſes which we are about to deſcribe in the large way in the third and fourth ſections.

§ 3. *Reduction of Ores.*

The richeſt gold mines concerning the working of which we have any very particular deſcription are thoſe of Hungary: the method of proceeding therefore in theſe eſtabliſhments ſhall be firſt mentioned.[f] The high commercial value of gold compared with that of any other metal depends in a conſiderable degree on its rarity, hence even the moſt profitable veins of gold are of trifling magnitude, and will pay very well to the miner though mixed very intimately with ſo large a proportion of ſtony gangue and other impurities as would render it impoſſible to work with advantage any other metal ſimilarly circumſtanced.

In the Hungarian mines the attention of the miner is not confined to the ſtrings of ore, but the whole contents of the vein are uſually extracted. It is raiſed for the moſt part in large maſſes to the ſurface, and is then diſtributed to the workmen, who break it firſt with large hammers and afterwards with ſmaller ones, till it is reduced to pieces of the ſize of a walnut or leſs. During this proceſs each piece is attentively examined and arranged according to its value: the native gold even to the ſmalleſt viſible grain is ſeparated as accurately as poſſible from the quartz in which it is chiefly imbedded, and put by itſelf; the auriferous galena and pyrites are alſo thrown into ſeparate heaps. The ſmall ſplinters detached during this proceſs, as well as the ſand and mud of the mine are alſo collected, waſhed and ſifted, and arranged according to their fineneſs and apparent richneſs. The portion rejected in this firſt examination is afterwards re-examined by boys, whoſe time is of little value, and who pick out nearly the whole of what has been overlooked by the men, and ſort in it the manner juſt mentioned.

The native gold with its adhering matrix is again broken by hand into ſtill ſmaller pieces, by which an additional quantity of impurities and ſtony matter is got rid of: it is then put into a kind of wooden box floored with caſt iron plates, and reduced to a fine powder by the action of two or more heavy ſpars of oak, ſhod with iron and worked alternately in the manner of a common ſtamping mill. This powder, or flour as it is called, being now removed into a convenient veſſel like a large baſon, is mixed with a ſufficient quantity of ſalt and water to render it damp, after which a workman takes a thin porous leather bag, puts a quantity of mercury into it, and by a continued regular preſſure forces the mercury in minute drops like dew through the leather: in this minutely divided ſtate it falls upon the pulverized ore, and is immediately kneaded up with it till the requiſite quantity (depending in great meaſure on the proportion of gold) has been added. This part of the proceſs being compleated, the mixture is rubbed together by means of a wooden peſtle for ſome time to expedite the incorporation of the mercury and gold, and is afterwards heated in a proper veſſel to about the temperature of boiling water for three or four days: finally, the mixture is waſhed very carefully by ſmall parcels at a time, the earthy particles are carried off by the water, and there remains behind only the mercury combined with the gold into an amalgam. Part of the mercury is then ſeparated by preſſure in a leathern bag, and the reſt is driven off by diſtillation, leaving behind only the gold and the ſilver with which it may happen to be alloyed. (For a fuller account of this proceſs ſee SILVER.)

Such is the ſimple method by which the native gold of the ore is extracted; a much more complicated proceſs however is required to ſeparate that portion of the metal which is diſperſed inviſibly in the pyrites, ochre, galena, and other metallic ſubſtances, as well as the ſtony parts of the gangue. Theſe in the ſorting already deſcribed, are ſeparated not only according to their apparent richneſs, but, what is of more importance, are alſo arranged according to their hardneſs. This being compleated they are transferred to the ſtamping mill.

The principal parts of a ſtamping mill are the following: 1. The coffers or ciſterns, uſually two in number, in which the ore is pulverized, and through which a ſtream of water that may be increaſed or diminiſhed at pleaſure, continually paſſes. 2. The ſtampers or vertical beams ſhod with iron. 3. The axle, fixed horizontally, and working at one end in a pivot and rivetted at the other into the center of a large water wheel. Hence the mode of its

[f] Delius, ſur l'art des Mines. vol. II. Born, &c.

action is evident: a ſtream of water falling upon the wheel turns it round, and at the ſame time the axle to which it is attached: the cogs faſtened upon the axle raiſe alternately the ſtampers to a given heighth, and then let them fall upon the ore that is placed in the coffers, which in proportion as it is ſufficiently comminuted, is carried by the water that is continually flowing through, out at the ſides of the coffer, into the labyrinths where the ſtony and metallic contents of the ore are depoſited nearer to or further from the diſcharging aperture, according to their reſpective ſpecific gravity.

The coffer is a rectangular hole ſunk below the level of the ground, and both floored and lined with ſtrong double oak planking: it is about four feet deep, five in length, and two feet or leſs in width. The ſtampers are five in number, and are ſtrong oaken beams terminated with iron, and weighing about 200 pounds each; they are placed ſide by ſide, about two inches and a half diſtant from each other. When any ore is to be pounded, the firſt thing is to cover the bottom of the coffer with a cloſe-ſet flooring or pavement, compoſed of large pieces of the hardeſt and pooreſt part of the vein, ſuch a floor being found by experience to be much better on many accounts than an iron one. The thickneſs of this floor is inverſely according to the hardneſs of the ore to be pounded; it being manifeſt that the higher this is the ſmaller will be the ſpace through which the ſtampers have to fall, and therefore the leſs will be their momentum: care muſt however at all times be taken that the part of the floor immediately beneath the middle ſtamper, is about two inches lower than that below the ſtamper on each ſide of the middle one, and that this again is about an inch lower than that beneath the two outermoſt ſtampers. The coffer being thus prepared, the ſtampers are ſet in motion by the water wheel, a ſmall ſtream is allowed to flow into the coffer, and the ore is thrown in juſt below the middle ſtamper, by a careful workman, or ſupplied in the proper quantity by a hopper: the ore being comminuted by this ſtamper, is gradually delivered to the next on each ſide, where it is ſtill further pulverized, and from which it is paſſed on to the two outermoſt ſtampers, by which it is at length reduced to grains of ſuch fineneſs, as to be for a time ſuſpended in the water, and carried by it through one or other of the apertures which are at each end of the coffer.

Much care is required, eſpecially in ſtamping the ores of gold and ſilver, in the firſt place that no pieces be ſubjected to the proceſs that can economically be ſeparated by hand from the gangue, for even when it is the moſt ſkilfully conducted a very notable proportion will be loſt; and ſecondly, that the ore be pounded either fine or coarſe, or be ſubjected to greater or leſs force according as circumſtances may require. If the ore is principally native gold diſperſed in very minute particles through quartz or hornſtone, it will be impoſſible to ſeparate the whole or nearly the whole of the metal, except it is reduced to exceedingly fine powder, and this may be ſafely done both becauſe the difference in ſpecific gravity between the two ingredients of the ore is very great, and alſo becauſe the quartz if reduced to particles ever ſo minute, does not at all clot and adhere to the gold. In this caſe therefore the floor of the coffer may be ſet as low as poſſible, to give the ſtampers their greateſt momentum, and only a very ſmall ſtream of water may be let in, that the current paſſing out of the coffer may carry with it only the ſmalleſt particles. It often however happens that the gold is diſſeminated in a very ochery and highly indurated clay, or in calcareous ſpar, and in this caſe there is only a choice of difficulties: if the ore is not extremely comminuted much of the metal will be kept in the earthy matrix, but if on the other hand the ſtamping is continued too long, the whole will be reduced to a fluid mud, which will prevent the thin laminæ of gold from ſubſiding; and long practice and accurate judgment are required to manage the proceſs ſo that the greateſt quantity of gold ſhall be obtained. Sometimes, as at Kremnitz, the gangue conſiſts partly of quartz and in part of indurated clay; in this caſe the moſt approved practice is, to raiſe the floor of the coffer to within about eighteen inches of the top, to put a moderate quantity of ore at once under the middle ſtamper, and to let on in the beginning of the proceſs a full ſtream of water; by this the clay as being the ſofteſt is battered to pieces, and carried off by the water before the quartz is ſufficiently comminuted to be waſhed out in any conſiderable proportion with it; the ſtream of water is then ſlackened, and the quartz is reduced to ſand of the requiſite fineneſs. There are few things that ſo much facilitate the waſhing ſubſequent to ſtamping, and upon which the product of metal ſo much depends, as the reduction of the gangue to grains of an uniform ſize; this is brought about by being careful that the ore when firſt put into the coffer, falls under the middle ſtamper, and

alſo by regulating the velocity of the water wheel; if the motion of the ſtampers is too ſlow, the only bad effect is loſs of time; but when their action is too much accelerated, the water is daſhed about and carries with it to the opening at the end of the coffer pieces of the ore that are not half ground, as well as thoſe that have gone through the whole proceſs: this fault is obvious not only from the difference in ſize between the grains, but thoſe which have not been ſufficiently pounded will be of a flat angular figure, and in conſequence will remain behind with the metal in the ſubſequent waſhing, inſtead of being carried off the tables together with the reſt.

When by the proceſs of ſtamping, the ore is reduced to particles of ſufficient fineneſs to be carried out of the coffer by the force of the water, it paſſes into ſhallow channels or troughs of various dimenſions, conſtructed either of wood or ſtone, and communicating at their extremities with each other; the whole ſeries is called a labyrinth. In theſe channels the various parts of the ore are depoſited, according to their reſpective ſpecific gravities; the heavieſt particles being detained in the firſt, and the lighteſt ſubſiding in the laſt and loweſt. Each of theſe channels is grooved at its lower extremity, to admit of its being cloſed at pleaſure by pieces of wood about an inch in heighth, which ſlide down upon each other like the planks in a Chineſe lock. It is obvious that the accuracy by which the heavy particles can thus be ſeparated from the lighter ones, will be much modified by varying the rapidity of the ſtream through theſe channels, ſo that at its outſet the ſtream ſhall be ſwift and its velocity ſhall gradually decreaſe as it paſſes ſucceſſively from one channel into another. This is effected by diminiſhing the ſlope and augmenting the width and length of the channels. Thus that which receives the water immediately from the coffer of the ſtamping mill is about four yards long, nine inches in depth and breadth, and has an inclination of two and a half or three inches; the ſecond is about five yards long, twelve inches in depth and breadth, and has one inch of inclination; the third and fourth are ſix yards long, with a depth and breadth equal to the former, and an inclination of half an inch; the fifth is ſeven yards long, fourteen inches in breadth, twelve in depth, and is not inclined at all; the ſixth is from eight to ten yards long, ſixteen inches in breadth, twelve in depth, and like the former is intirely level. When theſe channels are about to be uſed a ſlider about an inch high is put into the groove at the extremity of each, to prevent the grains which are depoſited from being rolled out and waſhed away by the force of the water: when the depoſit nearly attains the level of the top of the ſlider, a ſecond is put in, and thus the proceſs goes on till the channels are almoſt filled. The water from the coffer is now turned off into another labyrinth, and the contents of the former are taken out, care being taken not to mix what has ſubſided in any one channel with what has been depoſited in the others. By means of the foregoing proceſs, if carefully conducted, the metallic contents of the ore will be ſeparated in a conſiderable degree from the lighter ſtony particles: every thing however depends upon the ſkill and accuracy of the manipulation, more eſpecially where gold ores are thus treated, becauſe in this caſe the proportion of gangue to the ore is greater than in any other, hence even a moderate degree of careleſſneſs or of imperfection in the apparatus, will occaſion a loſs of full one fourth of the gold.

The firſt operation of waſhing, however carefully conducted, is by no means entirely adequate to the entire ſeparation of the ſand from the ore, it is therefore a ſecond time waſhed on what are called tables. Theſe are long planes of wood, conſiderably inclined (more or leſs according to circumſtances) and croſſed here and there at regular diſtances by narrow ſhallow grooves. To the upper extremity of the table is faſtened a long wicker baſket, or a perforated wooden trough, which is filled with waſhed ore; a little ſtream of water is then admitted, which paſſing between the twigs of the baſket trickles down upon the table, carrying with it particles of the ore, which are either carried entirely off the table by the impulſe of the water, or are depoſited in the grooves according to their ſpecific gravity, the heavieſt particles being ſtopped the ſooneſt. By this method the auriferous ores of iron and copper pyrites, galena, blende, &c. are ſufficiently ſeparated from the quartz and other ſtony matter to be fit for the ſmelting furnace; but the ores of native gold generally undergo a third waſhing, which is performed on ſmall quantities at a time, in a wooden veſſel called by Engliſh miners a buddle; its ſhape ſomewhat reſembles that of a common fire-ſhovel without a handle, only the ſides are more elevated in proportion, and it is furniſhed with two ears to hold it by. The ore being put in the veſſel is gently immerſed in water, and a circular motion is communicated to it by a peculiar ſlight of hand not to be deſcribed by words, by means of which the lighter particles

are by degrees thrown out of the buddle into the water, hardly any thing but the gold remaining behind, which is then either amalgamated or directly fused in an earthen crucible with the addition of a little nitre.

The gold that is found in alluvial foil or in the ſands of rivers, is obtained in preciſely the ſame way, except that it is not neceſſary to paſs it through the ſtamping mill previous to waſhing.

The proper auriferous ores being lighter than gold, and their contents being rarely of ſufficient value to admit of that accuracy in waſhing to which native gold is ſubjected, are always found after they come off the waſhing tables to be mixed with a very conſiderable proportion of ſtony matter. If the metallic part conſiſts of pyrites, as is uſually the caſe, it is adviſable previous to fuſion to give it a moderate roaſting in order to drive off the greater part of the ſulphur. The extent to which this proceſs ought to be carried depends in ſome degree on the quantity and refractorineſs of the ſtony part of the ore, for the ſulphur in the ſubſequent fuſion acting the part of a flux, it is obvious that the cleaner the ore is the more perfectly may it be roaſted. This being finiſhed, the ore is accurately mingled with a little quick-lime by way of flux, and with galena proportioned to the quantity of gold and ſilver that the pyrites contains according to the reſult of a previous aſſay. The mixture being now placed in a reverberatory furnace is made red hot, and as ſoon as it begins to clot together is ſtirred up from time to time and kept at a temperature inadequate to its fuſion till part of the ſulphur is driven off; this being effected the fire is increaſed, the whole is brought to a ſtate of thin fuſion and then let out in the uſual way into a mould of ſand. During the fuſion the iron, on account of its powerful affinity for ſulphur, reſumes the portion of which it had been deprived by the previous roaſting, by decompoſing the ſulphurets of lead and copper with which it is mixed, in conſequence of which theſe metals by their ſpecific gravity fall in drops through the vitreous ferruginous ſcoria, carrying with them the gold and ſilver, and unite at the bottom into a denſe metallic maſs. Hence the *pig* that is formed in the mould of ſand is found to conſiſt of two parts adhering to each other, but eaſily ſeparable by a hammer; the uppermoſt and by far the largeſt portion is more or leſs cellular and conſiſts of ſcoria, beneath which is a black heavy compact maſs containing the gold and ſilver, together with lead, copper, ſome ſulphur and iron. It is now broken into ſmall pieces and roaſted and fuſed once or twice more till all the ſulphur and other impurities are got rid of, nothing remaining but the gold, ſilver, lead and copper.

§ 4. *Refining.* [g]

Although the refining of gold generally relates to the ſeparation of this metal from ſilver and copper, theſe being the principal ſubſtances with which it is alloyed, yet it may with much propriety be conſidered as including all the methods of purifying gold from every other metallic admixture. In this ſenſe the term is uſed on the preſent occaſion, and we ſhall proceed to treat of it accordingly.

Separation of Gold from Lead and other metals by Cupellation.

The moſt economical method, and the only one habitually practiſed, of ſeparating gold from lead is by a proceſs called cupellation in the ſmall way, and teſting when practiſed on a large ſcale. The particular precautions requiſite in cupellation are deſcribed under the article ASSAY, as the method of teſting is under SILVER. All that is neceſſary to be ſtated here therefore, is merely the rationale of the proceſs. The cupel or teſt is a porous infuſible earthy maſs, with a ſhallow concavity at the top for the reception of the metal: this being placed in a furnace ſo as not to be in contact with the burning fuel, and a current of air at the ſame time paſſing over the ſurface of the teſt, the metal is brought almoſt to a ſtate of ebullition. At this temperature the lead is ſeparated from the gold in the form of a vitreous oxyd, which ſinking into the pores of the teſt leaves the gold behind nearly in a ſtate of purity, this latter metal being incapable of oxydation at any temperature by ſimple expoſure to heat and air.

Not only lead may thus be ſeparated from gold, but its effect as a flux in ſcorifying and carrying down moſt of the imperfect metals is ſo great that by means of the proceſs of cupellation with lead, repeated according to the proportion of the alloy and its affinity to the gold, theſe may alſo be got rid of nearly to the laſt atom. And this method is actually practiſed where the proportion of alloy is but ſmall; when however it exceeds a certain ratio it is more economical to have recourſe to the other methods detailed in this ſection.

It is to be obſerved however that when fine or pure gold is thus cupelled with lead, it always retains a ſmall portion of this metal, which

[g] Lewis, Comm. tech. Gellert Chem. Metall. Fleta minor.

however minute is ſufficient to impair both its colour and ductility. If beſides lead the mixture contains copper to the amount of one twenty-fourth of the gold, the whole of the lead will be ſeparated but hardly any of the copper. If in addition to the above ingredients the alloy contains a ſomewhat greater proportion of ſilver than it does of copper, this latter is ſeparated by cupellation and a little of the lead remains: but if the amount of ſilver is equal to or exceeds that of the gold, both the copper and lead may be compleatly worked off, the gold and ſilver remaining behind. Hence it is that the refiners in ſeparating the baſe metals from gold by cupellation, always add to the mixture a conſiderable proportion of ſilver.

Cupellation with lead alone does not ſucceed when gold is alloyed with tin: in this caſe the tin with part of the lead forms a very ſpungy and refractory oxyd, which floats upon the ſurface of the melted metal and retains a part of the gold. This difficulty however is ingenioufly obviated by the addition of ſome iron filings, which combine with the tin into an alloy that may be ſcorified by lead without any great trouble.

Separation of Gold from Antimony.

If the proportion of antimony exceeds that of the gold, the alloy, which will be very brittle, muſt be reduced to ſmall pieces and mixed with about a fourth of its weight of ſulphur and fuſed in a covered earthen crucible. When the fuſion is compleat it muſt be poured into a melting cone previouſly heated and greaſed, and when cool will be found to conſiſt of two parts readily ſeparable from each other; the upper will be ſulphuret of antimony holding a very little gold; the lower will be the reſt of the gold ſtill combined with regulus of antimony. The greater part of the antimony being thus ſeparated, the reſt may be got rid of by melting the alloy at a high heat and directing a ſtream of air from a pair of bellows into a crucible containing it, by which the antimony is oxydated and volatilized in the form of a white vapour. Shortly after this appearance has ceaſed and the gold has acquired a clear bright green colour, it is to be poured out, and being then remelted in a ſmaller crucible, together with ſome nitre, the laſt portions of antimony, if any ſhould happen to remain, will be compleatly oxydated and ſeparated from the gold. The ſmall quantity of gold detained in the ſulphuret of antimony may be procured by bringing it into thin fuſion and then precipitating part of the antimony by the addition of about a fifth of its weight of iron filings: the gold will fall down together with the antimony, and may be ſeparated in the way juſt deſcribed.

Separation of Gold from Silver and the imperfect metals by Sulphuret of Antimony.

By this method all the common imperfect metals except zinc may be ſeparated from gold: for in the firſt place gold is incapable of combining with ſulphur, and in the next place moſt of the other metals have a ſtronger affinity for ſulphur than antimony has. It is obvious therefore that if to an alloy of gold and copper, for example, be added ſome ſulphuret of antimony, the copper will become ſulphuretted at the expence of the antimony, which in its turn will combine with the gold.

Earthenware crucibles are the only ones that can be employed where ſulphuretted metals are concerned, but if theſe are uſed without any preparation they are extremely liable to crack and be corroded. The black-lead crucibles are fitter for this purpoſe than the common kind, but theſe laſt when prepared according to the method recommended by Scheffer are more durable and convenient than thoſe of black-lead. The preparation is very ſimple: take a well-burnt crucible and ſoak it for two or three days in linſeed oil, then clear away the oil to ſuch a degree as that ſome finely pulverized glaſs of borax being duſted over the inner ſurface may juſt adhere, let it then be ſet by in a dry place for two or three weeks and it is ready for uſe. In ſuch a crucible above two hundred fuſions, according to Scheffer, may be performed in ſafety.

The gold alloy being melted in the crucible, there is thrown in at two or three different times, about twice its weight of coarſely pulverized ſulphuret of antimony: at each addition the mixture froths and ſwells up ſo that the crucible muſt be large in proportion to the quantity contained; and eſpecial care muſt be taken to prevent any pieces of charcoal from falling in, as this would infallibly cauſe the melted matter to run over. If the purity of the gold as previouſly found by the aſſay is leſs than 16 carats, the crude antimony before it is added ſhould be melted with about a fourth of its weight of common ſulphur, by which too large an addition of antimony to the gold is avoided. As ſoon as the mixture ſparkles on the ſurface and is perfectly fluid, it muſt be poured into a melting cone previouſly heated and greaſed, and a tremulous motion by continued ſlight blows muſt be communicated to the mould to promote the ſettling of the precious

metal. When the matter in the cone is become ſolid, it may eaſily be got out by inverting the cone and giving it a few blows in this ſituation: it will be found to conſiſt of a reguline maſs of gold and antimony covered by a ſcoria compoſed of the former alloy of the gold united to the ſulphur of the antimony. The gold however ſtill retains a little of its alloy, and in conſequence requires to be again melted a ſecond or even a third or fourth time with the ſame quantity of ſulphuret of antimony. From theſe laſt fuſions the gold receives only a ſlight addition of antimony, as this metal unites with it only in proportion as it is deprived of its own ſulphur by the ſmall portion of alloy yet remaining in the gold. Theſe proceſſes being duly performed, the antimony is to be ſeparated in the manner already deſcribed and the gold remains perfectly pure. Where the proportion of antimony is conſiderable, it is likely that its ſeparation from the gold, which is uſually a tedious buſineſs, might be expedited by a judicious fuſion with ſulphur, which converting part of the antimony into ſulphuret would cauſe its ſpontaneous ſeparation from the reſt. The metals from which gold may be purified with particular advantage by means of antimony are iron, copper, tin, lead and ſilver.

Separation of a ſmall quantity of Gold from a large quantity of Copper.

In old gilt copper wire, button-makers' clippings, and auriferous copper from Japan and other places, although the proportion of precious metal is too great to be neglected, yet it is by no means ſufficiently large to admit of ſeparation by the cupel or by ſulphuret of antimony. The proceſs of eliquation, or of fuſing the copper with a large quantity of lead, and then expoſing the mixture to a heat capable of melting out this latter while the former ſtill continues ſolid, although practiſed with ſucceſs in the ſeparation of ſilver from copper has been repeatedly attempted in vain for the extraction of gold. But the following method, firſt publiſhed by Alonzo Barba, may on this occaſion be reſorted to with good effect.

Let the copper be firſt melted and granulated by being poured into water; then heat the metal red-hot in a crucible, and project on it at different times portions of common ſulphur till the whole becomes black and brittle; then reduce it in a mortar or by any other convenient way to a fine powder and ſubject it to amalgamation in the ſame manner as the proper ores of gold; the mercury will diſſolve out the whole of the latter metal without exerting the leaſt action on the ſulphuret of copper, which may afterwards be brought to the malleable metallic ſtate by roaſting and fuſion, as already deſcribed in the article copper.

There is another method however ſtill more advantageous which may be employed for this purpoſe. Equal weights of ſulphur and litharge are to be mixed together and combined by haſty fuſion into a black ſparkling maſs: the gold-holding copper being then melted, the ſulphuretted lead is thrown in by ſmall quantities at a time till its amount nearly equals that of the copper. All the ingredients, in conſequence of the lead being in the ſtate of oxyd, unite together into an uniform maſs. When the whole is in compleat fuſion ſome finely pulverized charcoal is added at two or three ſeveral times, being carefully ſtirred in with a piece of ſtrong copper wire. The charcoal immediately deoxygenates the lead, which ſinking to the bottom in its metallic form, draws with it the whole of the gold alſo, leaving a ſcoria of ſulphuretted copper floating on its ſurface. The gold is afterwards freed from the lead by cupellation.

This ſame proceſs might no doubt be applied to the ſeparation of gold from iron.

Separation of gold from Silver.

If the proportion of gold is very ſmall, the beſt way of ſeparating it from the ſilver is by means of ſulphur. For this purpoſe the alloy is melted, and granulated by being poured into cold water kept conſtantly in agitation by a wicker bruſh or rod. Of the granulated metal from an eighth to a fifth is reſerved, and the reſt is well mingled with about an eighth of its weight of pulverized ſulphur, which readily adheres to the moiſt grains. This mixture is put into a covered crucible and gently heated for ſome time, that the metal may be thoroughly penetrated by the ſulphur: when this is effected, the fire is to be raiſed, and the maſs brought into fuſion. In theſe circumſtances it might be thought that the gold, on account of its great ſpecific gravity, having alſo no affinity with ſulphuretted ſilver, would fall in drops to the bottom of the crucible, and there unite into a maſs by itſelf. This however is not the caſe; the ſulphuretted ſilver forms a tough viſcous fluid, in conſequence of which the minute grains of gold are prevented from ſubſiding. When therefore the maſs has been in full fuſion about an hour, ſo that the ſulphur is compleatly united with the ſilver, and any accidental exceſs of it has burnt off, one third of the reſerved ſilver in grains is added, and as ſoon as melted is ſtirred with a wooden rod in order to mix it

very accurately with the other materials and thus bring it in contact with the gold with which it immediately combines. After another hour of fusion, a like quantity of grained silver is again added, and an hour after this the remaining third. The crucible is now kept carefully covered, and at a pretty high temperature for about three hours, its contents being well stirred up from the bottom at least once every half hour. At the end of this time the surface of the mass instead of exhibiting the dark brown colour of sulphuretted silver, will have become whitish in consequence of the escape of part of the sulphur, and some bright white drops of melted silver of the size of peas will also appear. The matter must now be poured into a greased cone with the usual precautions, and when cold will be found to consist of a mass of sulphuretted silver, resting upon a white metallic button about equal in weight to the added silver, and containing the whole of the gold that was at first mixed with the entire mass. If the sulphuretted silver retains any gold, this may be separated by fusion in an open crucible: part of the sulphur burns off, and a corresponding quantity of silver is reduced to the metallic state: this being mixed with the rest by being carefully and repeatedly stirred with a piece of stick will attract the whole of the gold remaining in the silver that is still sulphuretted, and being poured into a cone will collect in one mass at the bottom.

The gold-holding silver collected in these two operations being melted and granulated, is subjected to one or more repetitions of the same process till the silver that is left contains a sufficient quantity of gold to make it worth while to proceed to parting by aqua fortis. It is possible indeed to separate nearly the whole of the silver by means of sulphur, but when the silver comes to be rich in gold, the sulphuretted silver always takes up a portion of it which is not separable again entirely without repeated fusions, so that when the gold amounts to a twentieth of the silver, it is scarcely advantageous to attempt a further purification by means of sulphur.

It appears from various experiments that the affinity of gold for copper, and of silver for lead is considerably greater than that which subsists between gold and silver, and upon this is founded a very ingenious and economical method of separating the gold from old gilt lace or silver wire, which has been practised in Saxony to a considerable extent. The metal being granulated, one sixteenth of it is mixed with half its weight of litharge, and one eighth of sandiver, and is named the precipitating mixture: the next is mingled with an eighth of pulverized sulphur, and is brought into fusion in the same manner as already described. When the fusion is compleat, which is known by a kind of flashing at its surface, half of the precipitating mixture is added at three different times, with an interval of about five minutes between each, and the fusion is then continued about ten minutes longer. Part of the sulphuretted silver is then laded out with a small crucible made red hot, and the remainder being poured into a melting cone, there subsides to the bottom a quantity of metallic silver combined with the greater part of the gold. The sulphuretted silver being again melted, the remainder of the precipitating mixture is added in the same manner as at first, and a second portion of gold holding silver is thus procured. The sulphuret still retains a small quantity of gold, in consequence of which it is a third time fused, and a precipitating mixture, equal in weight to the preceding, but composed of an alloy of equal parts of copper and lead, is added, by which a third precipitate of gold-holding silver is thrown down, and the sulphuret has now lost all its gold.

The several metallic masses thus procured are melted with an eighth part of lead, then granulated, and subjected to exactly the same treatment by sulphur and the precipitating mixtures as at first. The silver thus obtained being now very rich in gold is granulated, mixed with a sixteenth of sulphur, and kept in fusion for about half an hour, without the addition of any precipitant: being poured into a cone, the sulphuret is separated from the metal, and this last is treated twice or thrice more with sulphur in the same manner. The metallic button which now begins to exhibit a yellow colour, is melted with a sixteenth of copper, then granulated and mixed with a sixteenth of sulphur: this mixture being first gently heated in a covered crucible, and then fused for about a quarter of an hour, is poured into a cone, at the bottom of which the gold is found, of a brass colour, and about eighteen carats fine. Its purification is then compleated by sulphuret of antimony, as we have already described.

When gold and silver are alloyed together in such proportions that the former of these metals is not much less than a sixteenth, nor greater than a fourth of the whole mass, the usual method of separating them is by means of nitrous acid, or aquafortis. The operation is

technically called *parting*, and differs from the proceſs deſcribed under the ſame name in the article Assay only in being performed in larger quantities, and without ſome of thoſe nice manipulations which are abſolutely neceſſary to the accuracy of an aſſay.

Silver is readily diſſolved in nitrous acid, while gold in ordinary caſes is not at all attacked by this menſtruum: in conſequence of which when this latter metal amounts to one third of the maſs, it combines with and protects by its own inſolubility a portion of the ſilver from the action of the acid: hence the neceſſity of avoiding too large a proportion of gold in the alloy. On the other hand, as the expence of nitrous acid is conſiderable, it is requiſite that the ſilver ſhould be rich in gold, to render this proceſs which is very convenient on many accounts, alſo economical. The refiner therefore will be careful not to uſe pure ſilver, but ſuch as contains a little gold, in lowering the fineneſs of ſuch as is too rich in gold to be ſucceſsfully parted by itſelf, and by every other contrivance will ſtudy to employ no more acid than is abſolutely neceſſary.

A proper ſelection being made of poor and rich ingots of mixed metal, the whole is melted in an iron crucible, and well mixed by repeated ſtirring: it is then laded out by a clean iron ladle, and granulated by being poured into cold water. The glaſſes in which the parting is performed, thence called parting glaſſes, are nearly of the figure of a truncated cone with a rounded bottom, about twelve inches high, and ſeven inches wide at the lower extremity: eſpecial care muſt be taken in the choice of them, that they are without flaws of any kind, well annealed, and of an equal thickneſs throughout. Each glaſs is to be charged with about forty ounces of metal, to which is added nitrous acid, already half ſaturated with ſilver, in ſuch quantity as to ſtand two or three fingers' breadth above the ſurface of the metal. Twenty or more of theſe glaſſes are placed in a ſand-bath, and a moderate heat is applied, gradually increaſing till by the time that the acid is ſaturated, it is nearly boiling. The nitrat of ſilver being now decanted off, a freſh quantity of ſtronger acid is added and is boiled on the metal till it is nearly ſaturated: by this time almoſt the whole of the ſilver is taken up, and the undiſſolved reſidue appears like a heavy brown mud, conſiſting of the gold divided into very fine particles, and a little ſilver. The nearly ſaturated acid is now poured off, and replaced by a third portion of ſtill ſtronger pure nitrous acid: this is made to boil, and is continued at the ſame temperature till the production of nitrous gas ceaſes and the bubbles become large, which is a ſign that the whole of the ſilver is diſſolved. The acid being poured out and reſerved for the firſt part of a future ſimilar proceſs, the gold is waſhed with repeated portions of hot water, till the waſhings give no ſtain to a piece of poliſhed copper on being dropped on its ſurface. The edulcorated gold-powder being dried, is mixed with a little nitre and borax and melted; and is then perfectly pure. The unſaturated nitrat of ſilver is reſerved for the next parting: that which is ſaturated is poured boiling hot into a large wooden bowl lined with copper, and in which are laid ſeveral copper plates: upon theſe the ſilver is precipitated in the metallic ſtate in conſequence of the ſuperior affinity of the acid for copper: the plates are from time to time cleared of their ſilver cruſt, in order to expoſe a freſh ſurface to the acid, and expedite the entire decompoſition of the nitrat of ſilver: this being effected, the nitrat of copper is poured off, the plates are ſcraped, and the ſilver after edulcoration, is melted with a little nitre, and is thus obtained pure. If the nitrat of ſilver be perfectly neutralized, its decompoſition by copper, goes on ſlowly and imperfectly: this inconvenience is however at once removed by the addition of a very few drops of nitrous acid. In proportion as the quantity of copper in the acid increaſes, and that of the ſilver diminiſhes, the remaining nitrat of ſilver requires more time and a greater heat to be decompoſed, and even after long continued boiling with copper, a ſolution of any of the neutral muriats will throw down a white precipitate of muriated ſilver: it would appear therefore to be a ſaving both of time and expence, when the action of the copper begins to be languid, to throw down the remainder of the ſilver by an addition of common ſalt. The nitrat of copper obtained in the proceſs of parting, is turned to good account by being employed in the preparation of *Verditer*, (ſee Copper, p. 336.) and from the nitrat of lime reſulting from this laſt, the acid is again procured by diſtillation in the uſual manner with green vitriol or ſulphuric acid.

Separation of Gold from Platina.

Platina being like gold one of the perfect metals, that is, unoxydable by ſimple expoſure to heat and air, cannot be got rid of by cupellation; nor can any of the various methods in which ſulphur or a ſulphuretted metal is employed as the precipitant, be made uſe of with

ſucceſs, for platina ſeems to have at leaſt as little affinity for ſulphur as gold itſelf has.

Mercury although capable of combining both with gold and platina, unites with the former much more readily than with the latter: upon this fact is founded a method of ſeparating theſe metals, which though imperfect, may be advantageouſly applied as a preparatory proceſs. When the gold contains ſo large a proportion of platina as to be brittle, it muſt be pulverized in a mortar; but if the alloy is ductile, it muſt be reduced to ſmall pieces by granulation. This being done, ſome mercury, ſeven or eight times the weight of the alloy, is to be heated to ebullition in an iron crucible, and the alloy, previouſly made red hot, is to be dropped into it, and the whole kept in digeſtion nearly at the boiling point for half an hour. The mixture being then emptied into an iron mortar and covered with hot water, is to be carefully triturated for ſome hours, renewing the water from time to time: by this means the gold will combine with the mercury, and a conſiderable proportion of the platina will riſe to the ſurface of the amalgam in the form of a black powder, which may readily be ſeparated. When by this means the alloy is purified as much as poſſible, the ſuperfluous mercury is ſeparated by ſtraining through a leather in the uſual way, and the ſtiff amalgam is freed from the reſidual mercury by diſtillation.

The gold ſtill holding a little platina, is now melted with thrice its weight of ſilver, and the mixture being granulated, is parted with aquafortis in the manner already deſcribed. Now it is a ſingular circumſtance that although platina by itſelf, or even mixed with gold is perfectly inſoluble in nitrous acid, yet when combined with a large proportion of ſilver, it is perfectly ſoluble in this menſtruum, giving it a dark-yelloviſh brown tinge. [h] When therefore this triple alloy is digeſted in nitrous acid, the ſilver and platina diſſolve, leaving the gold behind. Of the gold thus ſeparated and carefully waſhed, a few grains muſt be again melted with thrice their weight of ſilver, and treated with nitrous acid, in order to aſcertain whether the platina is entirely got rid of; for if it contains $\frac{1}{2}$ per cent. or even leſs, the acid inſtead of being colourleſs, will be very ſenſibly tinged, in which caſe the proceſs muſt be again repeated on the whole: this however is ſcarcely ever neceſſary where the previous trituration with mercury has been carefully performed. The ſilver contained in the nitrous ſolution, together with the platina, cannot be ſeparated by copper as is uſual in common parting, becauſe ſome of the platina would be precipitated at the ſame time; but if a ſolution of common ſalt is had recourſe to, the ſilver will be thrown down in the ſtate of muriat, and the platina will remain in ſolution.

Another and more compendious method of ſeparating gold from platina, is to diſſolve the alloy in nitro-muriatic acid, and to throw down the gold by the addition of carbonat of ſoda, or a *large* quantity of green ſulphat of iron, neither of which will at all decompoſe the ſolution of platina: the gold when precipitated is to be dried, mixed with a little nitre and borax, and fuſed, after which it will be in a ſtate of abſolute purity.

Purification of Gold by Cementation.

A very few words are neceſſary on this ſubject, as the proceſs is now we believe wholly obſolete. It has been already mentioned that nitrous acid is incapable of acting upon a ſmall quantity of ſilver or copper or other metals, by which gold may happen to be alloyed, where the proportion of this latter is ſo great as to cover and envelope the particles of alloy. This takes place however only when the acid is liquid, and applied at a temperature not exceeding that of ebullition: at a greater heat a much larger proportion of gold is required to prevent the action of the acid on the baſe metal, ſo that by perſeverance and judicious management the gold may be obtained nearly pure. The proceſs by which this is effected is called cementation, and is thus performed.

Take the impure gold and beat or laminate it till it is ſomewhat thinner than a guinea; then heat it red hot, and allow it to cool ſlowly, that it may be as ſoft as poſſible; ſelect a ſound cementing pot, which is an earthen veſſel ſhaped like a low hollow cylinder cloſed at one end, and cover its bottom to the heighth of about a finger's breadth, with a cement compoſed of one part of nitre, two parts of calcined ſulphat of iron, and two parts of powdered tiles ground together to a fine powder, and moiſtened with urine; upon this cement place a ſingle layer of gold plate, then another layer of cement, and ſo on alternately till the pot is full, obſerving that the upper as well as the under layer is of cement; then lute on very accurately a cover, and place the pot in a furnace, ſo that it may be kept at a moderate red heat for twenty-four hours, care being taken not to increaſe the temperature ſo as to endanger the

[h] Vauquelin's Manuel de l'Eſſayeur.

fuſion of the gold. At this heat the metal being ſoftened, and the acid being liberated in a very active ſtate, the gold is penetrated more or leſs by it, and the ſilver and other metals, except platina, that the gold may contain are corroded and oxydated. When the pot is removed from the fire, it muſt be carefully unpacked, and the gold plates boiled firſt in water and then in dilute nitrous acid, by which they will be ſeparated from the metallic ſalt and oxyd, and will be found when aſſayed to be conſiderably purer than at firſt. Every repetition of the proceſs renders the gold purer, but in a decreaſing ratio; ſo that it is not worth while to perſevere in it longer than four or five times.

If common ſalt is ſubſtituted to nitre in the cement mentioned above, muriatic acid gas will be liberated inſtead of nitrous acid, and will be found to be equally efficacious, acting only on the alloy of the gold; but care muſt be taken not to employ both nitre and muriat of ſoda in the ſame cement, otherwiſe nitro-muriatic acid will be produced, and the gold as well as the alloy will be corroded.

The only purpoſe to which cementation is now applied, is to give a ſuperficial and therefore in ſome meaſure fraudulent fineneſs to gold highly alloyed.

§ 5. *Phyſical properties of Gold, and preparation of Gold-leaf and Gilt-wire.*

The colour of pure gold by reflected light is a full bright yellow, verging on one hand towards orange, and on the other towards braſs-yellow: it is remarkable that gold fuſed with borax becomes conſiderably paler than uſual, and on the other hand when fuſed with nitre, it becomes more highly coloured, without any other perceptible change being induced by either of theſe ſalts: hence as this metal is reckoned beautiful in proportion to the fullneſs and brilliancy of its colour, the borax flux uſed by the goldſmiths is generally mixed with a ſufficient quantity of nitre to counterbalance its diſcolouring property. The colour of gold when in high fuſion is blueiſh-green, of nearly the ſame tint with that of gold by tranſmitted light: this latter may conveniently be obſerved by laying a leaf of gold between two thin plates of colourleſs glaſs, and holding it between the eye and a ſtrong light.

The ſpecific gravity of gold is only inferior to that of platina: with regard to its preciſe amount a conſiderable variation may be obſerved on comparing the reports of different authors, one ſtating it as high as 20. and another as low as 18.75. This difference is no doubt in part attributable to ſlight impurities in the gold itſelf, partly alſo to imperfection in the balances made uſe of, to differences of temperature, to the gold's being caſt in ſand or metal, to its being hammered or not, and to other cauſes which in the article *Alloy* we have briefly pointed out, as affecting the ſpecific gravity of metallic ſubſtances. According to an experiment by Mr. Ellicot, whoſe accuracy is well known, the ſpecific gravity of an ingot of gold refined by antimony, was = 19.184, and of the ſame when hammered, = 19.207. According to Lewis, the ſpecific gravity of fine gold at 53° Fah. amounted to 19.376. Briſſon reports the ſpecific gravity of fine gold in ingot to be = 19.258, and of the ſame when hammered, = 19.361.

In hardneſs this metal ranks ſomewhat above ſilver and below copper. It is extremely flexible, and ſo tough, that when at length by repeated bendings it is made to break, both the fractured pieces appear terminated by a wedge-ſhaped extremity. From its ſoftneſs and toughneſs it receives with perfect exactneſs the impreſſion of the dies in coining, and for the ſame reaſons it does not file freely, clogging up the teeth of the inſtrument in a very ſhort time. It poſſeſſes little elaſticity or ſonorouſneſs. It receives great brilliance from the burniſher, but not from the action of poliſhing powders. It is inodorous and inſipid. The tenacity of gold is by no means ſo great as was ſuppoſed by the earlier chemiſts; it is inferior in this reſpect to iron, copper, platina, and ſilver. A wire of gold $\frac{1}{10}$ of an inch in diameter, will ſupport about 254lbs avoirdupois, before it breaks. It is extremely malleable both when hot and cold, and very ductile.

In conſequence of the high commercial value of gold, it is ſcarcely ever employed in maſs, or in thick plates for ornamental purpoſes, but advantage has been taken of its remarkable malleability to reduce it into leaves of an almoſt incredible thinneſs, ſo that in this ſtate notwithſtanding its high ſpecific gravity, it will float in the air like a feather. Of the ingenious art called *Gold-beating*, we ſhall proceed to give a ſhort account. [1]

The gold ſelected for this purpoſe is as pure as poſſible; the quantity uſed at one time by the Engliſh artiſts is two ounces. This being melted in a black lead crucible with ſome borax, is poured into an iron mould previouſly heated and greaſed, by which it is formed into a plate ſix or eight inches long, and three-quarters of

[1] Lewis Comm. Techn.

an inch wide. This plate is heated red hot, in order to burn off the tallow, and is then extended by forging on an anvil, and afterwards paſſed between ſteel rollers, till it becomes a long ribband as thin as paper. The ribband is now cut into 150 equal pieces, each of which is forged on an anvil, till it is about an inch ſquare, after which they are well annealed. Each of the ſquares in this ſtate weighs ſix grains and four tenths, and in thickneſs is equal to $\frac{1}{160}$ of an inch. The 150 plates of gold thus produced, are interlaid with pieces of very fine vellum about four inches ſquare, and about twenty vellum leaves are placed on the outſides, the whole is then put into a caſe of parchment, over which is drawn another ſimilar caſe, ſo that the packet is kept cloſe and tight on all ſides. Being now laid on a ſmooth block of marble, from 200 to 600lbs. in weight, the heavier the better, the workman begins the beating with a round-faced ſomewhat convex hammer, called the *cutch* hammer, weighing ſixteen pounds; the packet is turned occaſionally upſide down, and beaten with ſtrong but not acute ſtrokes, till the gold is extended nearly to an equality with the vellum leaves, to aſcertain which the packet is opened from time to time, and alſo bent and rolled between the hands to facilitate the extenſion of the gold between the leaves. This firſt part of the proceſs being compleated, the packet is then taken to pieces and each leaf of gold is divided into four with a ſteel knife; the 600 pieces thus produced are interlaid with pieces of ox-gut, of the ſame dimenſions and in the ſame manner as the vellum. The beating is continued, but with a lighter hammer called the *ſhoddering* hammer, and weighing about twelve pounds, till the gold is brought to the ſame dimenſions as the interpoſed membrane. It is now again divided into four, by means of a piece of cane cut to an edge, the leaves being by this time ſo light that any accidental moiſture condenſing on an iron blade, would cauſe them to adhere to it. The 2400 leaves hence reſulting are parted into three packets, with interpoſed membrane as before, and beaten with the *finiſhing* or *gold* hammer, weighing about ten pounds, till they acquire an extent equal to the former. The packets are now taken to pieces, and the gold leaves, by means of a cane inſtrument and the breath, are laid flat on a leathern cuſhion, and cut one by one to an even ſquare, by a cane frame; they are laſtly laid in books of 25 leaves each, the paper of which is previouſly ſmoothed and rubbed with red bole, to prevent them from adhering. Hence it appears that each of the inch-ſquare pieces, into which the ribband of gold was divided, is extended by beating to 196 ſquare inches, or 16 leaves, weighing 0.4 of a grain each, and not exceeding in thickneſs $\frac{1}{150138}$ of an inch. Every grain of gold furniſhes 30.6 ſquare inches.

Gold wire, as it is called, is in fact only ſilver wire gilt, and is prepared in the following manner. A ſolid cylinder of fine ſilver weighing about twenty pounds, is covered with thick leaves of gold which are made to adhere inſeparably to it by means of the burniſher: ſucceſſive laminæ are thus applied, till the quantity of gold, if intended for common gold wire, amounts to 100 grains for every pound troy of ſilver; if for double gilt wire, to about 140 grains. This gilt ſilver rod is then drawn ſucceſſively through holes made in a ſtrong ſteel plate till it is reduced to the ſize of a thick quill, care being taken to anneal it accurately after each operation. The ſucceeding proceſs is ſimilar to the former, except that a mixed metal ſomewhat ſofter than ſteel is employed for the drawing plates, in order to prevent the gilding from being ſtripped off, and no further annealing is requiſite after it is brought to be as ſlender as a crow-quill. When the wire is ſpun as thin as is neceſſary, it is wound on a hollow copper bobbin, and carefully annealed by a very gentle heat: finally it is paſſed through a flatting mill, and the proceſs is compleat.

According to Dr. Halley, ſix feet in length of the fineſt gilt wire before flatting, will counterpoiſe no more than a grain: and as the gold is not quite $\frac{1}{37}$ of the whole, a ſingle grain of gold thus extended will be 345.6 feet long. By the operation of flatting, the length of the wire is increaſed about a ſeventh, and its width is equal to $\frac{1}{96}$ of an inch: hence the ſurface occupied by one grain is equal to 98.7 ſquare inches, with a thickneſs of $\frac{1}{490444}$ of an inch.

§ 6. *Chemical properties of gold.*

Gold requires for its fuſion a low white heat equivalent to 32° of Wedgwood, or 1300 of Fahrenheit, and in this ſtate its ſurface appears of a luminous blueiſh green colour. It expands leſs than moſt metals by any addition of heat as long as it continues ſolid, but is enlarged more than any other during its paſſage from ſolidity to fluidity, hence it is peculiarly unfitted to take a ſharp impreſſion from caſting, and hence alſo it is very apt to prove brittle if ſuddenly congealed, as by pouring into a cold mould. When divided into ſmall parts, as

filings, and heated, although each particle is perfectly fluid, it is extremely difficult to make them unite into one mafs without having recourfe to fome faline flux, and none is fo efficacious for this purpofe as borax, which accordingly is employed by the goldfmiths on all occafions, even when apparently it is not at all wanted. If cooled very flowly it fhews a ftrong tendency to cryftallization in the appearance of brilliant facets on its furface like the petals of a flower, and by pouring off the fluid part when it is half congealed, it may be obtained in fhort tetrahedral prifms. No vapour arifes from gold when in fufion, and its remarkable fixity is proved by Kunckel who kept a quantity for almoft thirty weeks in the high temperature of a glafs-houfe furnace without the lofs of a fingle grain, or any other alteration. When a fmall portion however is expofed in the focus of a very powerful lens, or fubjected to the action of a ftream of oxygen gas, it is volatilized unaltered and will gild a plate of filver held over it.

The poffibility of altering gold by expofure to heat and air has long been a fubject of controverfy, nor do modern chemifts feem by any means agreed on this point: there appears however no good reafon to doubt that gold may be thus oxydated by particular management, though many of the facts ufually brought in proof of it, are without queftion erroneous. Homberg affirms that a fmall quantity of gold placed upon charcoal and fubjected to the action of a very powerful lens, began to fmoak, and was in part vitrified. Of the fact there is no reafon to doubt, but the vitrefied portion in all probability conffifted of the afhes of the charcoal, coloured by fome of the alloy of the gold, as indeed was the opinion of fome of the affiftants at this very experiment. We have already cited the teftimony of Kunckel to fhow the unalterability of gold, by the continued action of a high temperature, but the fame chemift affures us, that this metal when prepared in a particular way, and expofed in fine powder to the action of a reverberatory furnace not fufficiently hot to melt it, is at length converted into an irreducible calx. It appears likely, that the preparation here alluded to, was alloying the metal, probably with tin: for in this ftate it is pulverizeable, and by a treatment fimilar to the one here mentioned, is entirely convertible into a fpungy oxyd of a purple colour, and difficult reduction. This effect of the tin does not appear to be owing to any chemical action on the gold, but merely to its feparating the particles of this metal from each other, in which ftate it is reducible into a purple oxyd without much difficulty: for "if gold leaf be divided by grind-"ing with an admixture of earthy powders, as "calcined hartfhorn and chalk, or with faline "ones of the more fixed and lefs fufible kind, "as vitriolated tartar, and expofed for fixteen "or twenty hours to a moderate heat, fcarce "fufficient to keep the veffel red hot: the gold "wholly lofes its metallic brightnefs, and changes "its yellow colour to a red or purple." [k] From this mixture the falt may be diffolved out by water, or the chalk by a weak acid, and the pure oxyd of gold remains behind. Gold may in like manner be converted into a purple oxyd by a ftrong difcharge of electricity, as is manifeft from the common experiment of paffing a fhock through gold-leaf laid between two plates of glafs, and thus tinging the glafs purple; and ftill more decidedly from an experiment of Van Marum, in which a gold wire was ignited by electricity, and volatilized with a green flame; the vapour being condenfed, proved to be the purple oxyd of gold. The relative proportions of the two ingredients in this oxyd have not been afcertained. When expofed to a full red heat it is decompofed, the oxygen flying off, and the gold in its metallic ftate remaining behind.

If gold is precipitated by a fixed alkali from its folution in nitro-muriatic acid, a yellow oxyd falls down, which is fuppofed by Dr. Thomfon to differ from the purple oxyd in containing a larger proportion of oxygen: no experiments have however as yet been inftituted to afcertain this point. The yellow oxyd is reducible *per fe* with the fame eafe as the other.

Gold in its metallic ftate appears to be acted on only by the following among the claffs of acids, viz. the nitric, nitro-muriatic, and oxy-muriatic acids.

Pure colourlefs *nitric* acid is incapable of diffolving reguline gold alfo pure: but if the acid is highly charged with red nitrous vapour, and in this ftate is digefted on gold-leaf, in a retort or other clofe veffel, the metal is readily taken up. This fact was firft difcovered by Dr. Brandt in the following manner. Wifhing to feparate the filver from an alloy compofed of 16 parts of filver and 3 of gold, he placed the mixture in an alembic with an attached receiver, and boiled on it fucceffive portions of nitric acid, increafing the ftrength of it as he proceed-

[k] Lewis, p. 74.

ed: when nearly the whole of the ſilver was ſeparated by this means, a freſh quantity of acid was added, and boiled nearly to dryneſs: this reſidue being mixed and boiled with more acid, a yellow coloured liquor was obtained, holding not only ſilver but gold in ſolution, as was evident from its depoſiting a conſiderable quantity of this latter in the metallic ſtate, when digeſted with an additional portion of pure ſilver. By long keeping, part of the gold ſeparated ſpontaneouſly in the form of a brown powder, but much ſtill remained in ſolution as long as the external air was excluded. If ſome of this nitrat of gold be put into a vial and well ſhaken, ſo that the air which it contains is intimately mingled with the liquor, the gold according to an obſervation of Scheffer quickly and entirely ſeparates from the acid.

The uſual and moſt powerful ſolvent of gold is *nitro-muriatic* acid, prepared by adding to two parts of ſtrong aquafortis, one of fuming muriatic acid, or one half part of common ſalt, or muriat of ammonia. The moſt economical, however, and upon the whole the beſt way of diſſolving gold in this acid, is to put the granulated metal together with ſix times its weight of nitric acid, into a tubulated glaſs retort with a receiver annexed: the contents of the retort being warmed by a lamp, or a pot of charcoal, a little ſtrong muriatic acid is to be poured in: an effervеſcence and copious extrication of nitrous gas will take place, and the gold will begin to be acted on: as ſoon as the gas ceaſes to be produced, a freſh quantity of muriatic acid is to be added, and ſo on till the gold is diſſolved. The liquor being now made to boil, all the nitric acid which has eſcaped decompoſition will diſtil over almoſt entirely unmixed with muriatic acid, a little of which laſt however will riſe towards the end of the proceſs in white fumes. Thus none of the nitric acid will be waſted, and the ſolution remaining in the retort will be pure muriat of gold. The colour of this ſolution is a bright yellow, it is very cauſtic, and has a ſtrongly aſtringent metallic flavour. It gives a permanent deep purple ſtain to the fingers, and to almoſt all animal and vegetable ſubſtances; it even ſinks deeply into marble, and communicates to it a ſimilar tinge. In theſe caſes the gold is no doubt converted into the purple oxyd. By ſlow evaporation and cooling, the liquor depoſits ſmall cryſtals of a yellow colour, in the form of four-ſided priſms, or truncated octohedrons: theſe may be obtained with more certainty, if the liquor after evaporation is diluted with a little warm alcohol. If the evaporation is very ſlow, and the light at the ſame time freely admitted, only a ſaline amorphous maſs is depoſited of a high red orange colour: nor can regular cryſtals be procured, according to Monnet, if either muriat of ammonia, or common ſalt enter into the compoſition of the aqua regia. By diſtillation at a very low red heat, muriat of gold is entirely decompoſed, the acid eſcaping in the form of white vapour, and the metal in a reguline ſtate remaining behind. If the ſalt has been prepared with *rough unſublimed* ſal-ammoniac, and the heat is ſuddenly increaſed when nearly the whole of the liquid has been diſtilled off, there riſes together with muriatic acid ſome very red muriat of gold, which diſſolving in the fluid contained in the receiver, forms a ruby coloured liquor, named by the alchemiſts *leo ruber*, and ſuppoſed by them to poſſeſs many wonderful properties.

The alkaline earths both pure and carbonated, throw down from a ſolution of muriated gold, a yellow oxyd, which by expoſure to the air acquires a purple colour, and at a red heat, is reducible *per ſe* to the reguline ſtate.

The fixed alkalies precipitate the oxyd of gold in the form of a browniſh yellow ſediment, which when waſhed and heated becomes firſt purple and then aſſumes its metallic appearance. If a perfectly carbonated alkali is made uſe of, the only precaution requiſite is to dilute the metallic ſolution with three or four times its bulk of water before pouring in the alkali, by which management, the ſubſidence of the precipitate will be expedited, more eſpecially if the mixture is boiled for a minute in a glaſs-veſſel. If however an alkali in part or entirely cauſtic, is made uſe of, care muſt be taken, after diluting the ſolution to drop in the alkali by degrees, and only ſo long as it cauſes a viſible precipitation: if after ſtanding twenty-four hours to allow the oxyd to ſubſide, the ſupernatant liquor is ſtill coloured, a little more alkali may be added. But if inſtead of this cautious proceeding, an exceſs of alkali is poured in at once, the liquor aſſumes a light purple tinge, ſome of the gold is rediſſolved by the alkali, and it will be ſeveral months before the whole of the metallic oxyd is ſeparated.[1]

In the decompoſition of muriated gold by means of the fixed alkalies, the action of theſe ſubſtances appears to be confined to the ſaturation of the acid; and in conſequence of the ſtrong affinity ſubſiſting between theſe two, the

[1] Beaumé Chim. exp. iii. p. 71.

oxyd of gold is precipitated, while the ſupernatant liquor holds in ſolution the neutral muriat. The metallic oxyd after being well waſhed ſeems to be perfectly pure, and is decompoſable at a low red heat, merely in conſequence of the very weak attraction of gold for oxygen. Ammonia differs in this reſpect very materially from the fixed alkalies: its affinity for the oxyd of gold is remarkably powerful, and in conſequence, it decompoſes the ſalts of this metal, not only by means of its affinity for the acid, but alſo for the baſe, hence the precipitate is not a mere oxyd, but an ammoniuretted oxyd, and it exhibits, as we ſhall proceed to ſhow, very remarkable properties.[m]

Ammoniuret of gold, or *fulminating gold*, is prepared in the following manner. To a ſolution of muriated gold, diluted with ſix or eight times its bulk of diſtilled water, add liquid ammonia drop by drop, till it ceaſes to occaſion any precipitate: ſeparate by means of the filter, the yellow powder that will be thus produced, waſh it well in two or three parcels of hot water, and let it dry in the air or in a warm room. The fulminating gold thus procured, will be found to exceed the weight of the original gold by about 33 on the hundred, or in other words, out of 100 parts of this compound 75 will be gold. If a little of this powder, half a grain for example, is held over a candle, in a ſpoon or on the blade of a knife, it ſhortly explodes with a loud ſtunning report, from which circumſtance it has obtained its common appellation.

Although the proceſs which we have juſt given is perhaps the ſimpleſt method of preparing this dangerous ſalt, yet ſo powerful is the affinity of ammonia for oxyd of gold that if the two come into contact with each other under a'moſt any circumſtances, they will eagerly combine together. Thus if the gold inſtead of being diſſolved in pure aqua regia is diſſolved in one made by mixing nitric acid with muriat of ammonia, the precipitate thrown down from this even by a fixed alkali will poſſeſs the property of fulminating. Again, if oxyd of gold thrown down from pure aqua regia by a fixed alkali be rediſſolved in either the ſulphuric or nitric acids and precipitated by ammonia, the reſult will be fulminating gold. If even the ſimple oxyd of gold, previouſly boiled with cauſtic fixed alkali in order to ſeparate any adhering acid, be digeſted for ſome hours in liquid ammonia, it will become equally fulminating as by any other mode.

The effects of this compound when exploded, though not ſo violent as thoſe of fulminating ſilver, are ſufficiently dangerous to juſtify the greateſt caution in uſing it. The preciſe degree of temperature requiſite for its exploſion is not aſcertained, and indeed appears to be ſubject to ſome variation; it may however be ſtated as above 250° of Fahrenheit's thermometer. Juſt before it explodes, its colour changes from yellow to black, and a momentary flaſh is obſervable at the inſtant of its decompoſition. Although it exerts its force in all directions, yet its principal energy is in a downward direction; hence two or three grains exploded on a piece of moderately thick ſheet copper will tear a hole in it. An electrical ſhock will alſo decompoſe this ſalt, but it cannot be ſet fire to by a ſpark either of electricity or from the flint and ſteel. By ſudden friction it explodes with great vehemence, and ſeveral inſtances are recorded of ſerious accidents from this cauſe: hence it ſhould never be kept in a ground-ſtoppered bottle, as a little may adhere in the neck and will be infallibly exploded by the inſertion of the ſtopper. The facility with which this powder explodes is prodigiouſly increaſed by high drying; if it is heated till it becomes black and is immediately removed from the fire, it will then go off frequently by a mere touch. The grains of this ſubſtance have not like thoſe of gunpowder the property of communicating the decompoſition from one to another; only thoſe that are heated to the preciſe point are exploded, the reſt are diſperſed unaltered by the violence of the ſhock. Its proper exploſive force, though attended with a loud report, ſeems however to be conſiderably inferior to that of gunpowder, hence if heated in a pretty ſtrong cloſe veſſel it is compleatly decompoſed but without any ſhock.

There appears to be no ſubſtance capable of ſeparating the ammonia from the oxyd of gold after they are once united, and the only mode of decompoſition is the application of ſuch a heat as ſhall at the ſame time deoxydate the gold and reduce the ammonia to its elementary parts. By a dry heat this decompoſition is moſtly rapid and exploſive, but by the intervention of a hot liquid it is gradual and ſilent. Thus the fixed alkalies, whether cauſtic or carbonated, if diluted with water ſo that their boiling point is inferior to the heat required for the decompoſition of fulminating gold, may be digeſted upon it without in the ſlighteſt degree impairing its characteriſtic property, but when

[m] Bergman's Eſſ. ll. p. 135. Baumé Chim. exp. Lewis comm. techn.

ſo far concentrated as to require a much higher temperature for their ebullition, they gradually decompoſe it without however diſengaging any ammonia. In the ſame manner diluted ſulphuric acid produces no effect, though when concentrated it effects a decompoſition, but merely in conſequence of the greater quantity of heat which it requires for ebullition. Nitric acid even when moſt concentrated boils at a lower temperature than is required for the decompoſition of this ſalt, and therefore produces no effect on it. Muriatic acid ſparingly diſſolves it, but on the addition of a little fixed alkali lets it fall again unaltered.

If aurum fulminans be mixed with four or five times its weight of chalk, or ſulphat of potaſh, or in ſhort with any pulverulent ſubſtance neither fuſible nor decompoſable at a moderate temperature, and is expoſed gradually to a low heat it will be quietly decompoſed, nothing of the ſalt remaining behind but the purple oxyd of gold. A ſimilar effect may be produced, only that remarkable caution is required, by heating the fulminating gold without any addition; as ſoon as it changes colour at all it is to be removed from the fire, and when cold again heated till the colour is a little more deepened, proceeding in this way till the powder becomes purple it will be found to have entirely loſt its exploſive faculty. A ſimilar change takes place if ſome ſulphur is melted at the loweſt poſſible heat and the fulminating gold is dropped in by half a grain at a time and well mixed: the ſulphur may then be burnt off without any danger, and minute grains of metallic gold will be left behind.

The true theory of the decompoſition of fulminating gold was partially diſcovered by Bergman, and has ſince been fully illuſtrated by Berthollet. The former of theſe able chemiſts ſhowed that this ſalt when decompoſed in cloſe veſſels was reduced to gold partly in the metallic ſtate and partly in that of purple oxyd, and at the ſame time a gas was extricated in bulk about a thouſand times as great as that of the original fulminating ſalt, and which extinguiſhed flame and animal life, was not abſorbed by water and gave no precipitate with lime-water. Berthollet, by decompoſing the ſame ſubſtance in a copper tube connected with a jar inverted in mercury, obtained azotic gas and a few drops of water, and the gold was reduced to the metallic appearance. Now as ammonia is compoſed of hydrogen and azot, and as the affinity of gold for oxygen is very ſlight, it is manifeſt that the decompoſition and exploſion under the circumſtances already mentioned, are occaſioned by the oxygen of the gold and the hydrogen of the ammonia combining to form water, and to the liberation of the azot and its ſudden aſſumption of the gaſeous ſtate.

Muriat of gold may be decompoſed not merely by the ſuperior affinity of certain ſubſtances for its acid, or of others for the metallic oxyd, but alſo in conſequence of yielding a part of its oxygen to baſes whoſe attraction for this ſubſtance is particularly powerful. Thus if a little muriat of gold is poured into ſulphureous acid, this laſt in a ſhort time deprives the metallic ſalt of part of its oxygen, and in conſequence the ſurface of the fluid is covered with a film of reduced gold: the ſame takes place if gallic acid is made uſe of. So alſo if ether and muriat of gold are ſhaken together, the water firſt gives up the metallic ſalt to the ether and becomes itſelf colourleſs, while the ether aſſumes a bright yellow tinge, and after a while the gold is deoxydated by the combined action of the water and ether, and is ſeparated in its metallic ſtate. In the ſame manner a ſtick of phoſphorus being immerſed in muriat of gold will in a few days be covered with a brilliant coating of this metal: and a ſimilar effect is produced, according to Count Rumford, by charcoal, provided its action is aſſiſted by a boiling heat or by expoſure in a cloſed vial to the rays of the ſun. Hydrogen gas alſo is capable of decompoſing muriat of gold as well as other metallic ſalts while they are moiſt with water;[n] thus if a piece of ſilk is dipped in muriat of gold and expoſed in a cloſe veſſel to hydrogen gas, it will in a ſhort time be covered with a pellicle of gold, partly metallic and in part in the form of purple oxyd.

Certain of the metals and metallic ſalts decompoſe muriat of gold accompanied by peculiar phenomena, which we ſhall proceed to mention.

If a piece of clean iron is introduced into a dilute ſolution of muriated gold, this latter metal is precipitated upon the ſurface of the iron in the reguline ſtate, a proportional quantity of the iron being diſſolved. If the ſolution is largely diluted with alcohol inſtead of water, the gold precipitates upon the iron and a very little of this latter is in return taken up by the dulcified acid; the gold may be made to adhere firmly to the ſurface of the iron by burniſhing, and this is the moſt convenient and economical method of gilding iron. The red ſulphat of

[n] Mrs. Fulhame's Eſſays.

iron, being fully charged with oxygen, has no effect on muriat of gold, but the green fulphat entirely decompofes it, being itfelf convertible to red fulphat and the gold falling down for the moft part in the metallic ftate.

Copper acts with remarkable energy on muriat of gold: as foon as immerfed in this fluid it becomes fuperficially of a blackifh red colour, and after a while the gold fubfides in its metallic ftate but with a reddifh tinge, no doubt from its being mixed with copper. When the whole of the gold has fallen down the liquor becomes colourlefs, as was obferved both by Lewis and Beaumé; this however does not prove that the folution contains little or no copper, as thefe chemifts fuppofe, but the direct reverfe; for when muriat of copper is at its minimum of oxydation, that is when it contains the greateft poffible quantity of metal in proportion to its oxygen, the falt is entirely colourlefs, being the white fub-muriat recently difcovered by Prouft. Sulphat of copper is incapable of decompofing gold. Acetite of copper feparates the gold in brilliant metallic films, which adhere to the fides of the veffel; in this cafe however it is probable that the acetic acid contributes to the decompofition at leaft as much as the copper.

Zinc, bifmuth and mercury decompofe the muriat of gold, throwing down the metal in the reguline ftate. The action of the falts of thefe metals on the fame has not been examined into with any accuracy. Orfchal [o] fays that nitro-muriat of mercury precipitates gold of a remarkably bright purple colour, fuperior in this refpect to Caffius's precipitate.

Silver and lead precipitate the gold from its muriat in the form of purple oxyd. The fame takes place when the nitrats of thefe metals are employed; a copious depofition of muriated lead or filver takes place mixed with the purple oxyd of gold. Tin likewife decompofes muriat of gold, and feparates from it a purple oxyd. For this purpofe let the metallic falt be largely diluted with water and put into a glafs or glazed earthenware veffel together with a few pieces of grain tin: in a fhort time the liquor will become of the colour of red wine, and a very light flocculent precipitate will begin to feparate, leaving the liquor entirely clear: this being poured on a filter and waffied repeatedly with warm water is then to be dried; it now appears as a deep purple powder, and is ufed by enamellers and makers of artificial gems as the colouring matter for the fineft red glafs. A fimilar effect is produced by ufing recently made muriat of tin inftead of the pure metal, this falt having a remarkably ftrong affinity for oxygen, and therefore eafily throwing down the gold in the ftate of red oxyd. Even nitro-muriat of tin, if newly made at a low temperature, will be nearly as efficacious as the fimple muriat, and this method of preparing the purple colouring matter having been invented by Dr. Caffius more than 150 years ago, has fince been familiarly known by the name of Caffius's purple powder or precipitate. The ancient method of preparing it was the following. [p] Into about two quarts or more of diftilled water, drop firft about a fcruple of a folution of gold in aqua regia, and then add a like quantity of a folution of tin in nitro-muriatic acid; when the purple precipitate thus produced has fubfided a little, add a few drops more of tin as long as any further precipitate takes place; then throw the whole on a filter, wafh it repeatedly and dry it. This mode however is liable to feveral objections: it very often happened that the tin was fo highly oxygenated as to be wholly incapable of throwing down any precipitate; in this cafe the addition of fome grains of metallic tin was requifite; but though this was effectual in decompofing the muriated gold, it alfo at the fame time threw down fome oxyd of tin which confiderably impaired its ufe as a colour for tranfparent glaffes. Sometimes, efpecially if the liquor was not enough diluted and the gold was added to the tin, inftead of the tin to the gold, only a muddy bluifh brown precipitate was obtained. Another inconvenience attending the practife of the ancient chemifts in this matter was, that the aqua regia in which they diffolved the gold was almoft always made with nitric acid and muriated ammonia, in confequence of which the red powder very often poffeffed a fulminating property, and thus occafioned many ferious accidents.

Befides the nitric and nitro-muriatic acids, gold is alfo capable of being diffolved by the oxymuriatic acid. This fact was firft afcertained by Scheele. The folution however when compleated appears to be merely muriat of gold, the fuperabundant oxygen being entirely employed in oxydating the gold previoufly to its becoming foluble in the acid, now changed into fimple muriatic acid.

The oxyd of gold precipitated from the muriat by either of the carbonated fixed alkalies is foluble, as Bergman has fhown, in the fulphuric and various other acids; but the falts hence refulting have not as yet been examined.

[o] Sol fine veſte; in Neri's Art. de la Verrerie. [p] Ibid.

Of the neutral falts nitre appears to be the only one capable of acting on metallic gold: on this fubject Mr. Tennant has publifhed the following intereffting particulars. [q] A golden tube was filled with nitre and thin pieces of gold, and expofed for two or three hours to a ftrong red heat; by this procefs part of the nitre was converted into cauftic potafh and part into nitre more or lefs deoxygenated, or according to the reformed nomenclature, nitrite of potafh. Of the gold a confiderable quantity was changed into a black powder, feparable from the alkali and other faline matter by mere wafhing, but another portion of gold equal in weight to a fifth of the black powder, remained in folution, communicating to the liquor a yellow colour. By dropping into this folution diluted fulphuric or nitrous acid, it became at firft of a deep yellow, but if viewed by tranfmitted light, it foon appeared green, and afterwards blue, from the gradual precipitation of the gold in its metallic ftate. But although the metal is thus precipitated in its reguline ftate, it appears while in folution, to be in the form of oxyd, and to be afterwards thrown down, only becaufe its oxygen is gradually abftracted by that portion of nitre which has been partially decompofed. In proof of this, it may be further remarked, that even muriat of gold, if confiderably diluted with water, is decompofable by nitre that has been partly deoxygenated by heat, the gold being precipitated in the *metallic* ftate, which could not happen if the alkali alone of the nitre had been concerned.

The affinity between gold and fulphur, if it exifts at all, is never fufficiently efficacious to produce a combination between thefe two fubftances: but fulphuret of potafh or foda will diffolve leaf gold by fufion without difficulty. The compound thus produced, is perfectly foluble in water, and may be paffed through a filter without depofiting any of the gold. The addition of an acid throws down both the fulphur and the gold: but whether this latter is in the ftate of hydrofulphuret or not, has not been afcertained: if the mixed precipitate is gently heated, the fulphur is evaporated or burnt off, and the gold in its metallic ftate remains behind.

The only one of the fimple combuftibles with which gold has hitherto been found capable of combining, is phofphorus. This fact appears to have been firft noticed by Pelletier: [r] he mixed half an ounce of gold with an ounce of vitreous phofphoric acid and a drachm of charcoal, and by heating the mafs, inclofed in a crucible, for an hour in a furnace, he obtained a metallic button, weighing about four per cent. more than the gold employed, of a whitifh colour, and exhibiting on its furface marks of cryftallization: it was perfectly brittle, but by being kept for fome time in fufion on a cupel, the phofphorus was burned off, and the gold refumed its ufual characters. Phofphuret of gold may alfo be prepared by heating gold filings to redneis in a crucible, and then dropping on them a few fmall pieces of phofphorus, the mafs foon enters into fufion, and the refult is a button of phofphuretted gold, refembling in every refpect that procured by the former method. From thefe facts as afcertained by Pelletier, we may explain an experiment of Glauber, mentioned in his treatife *de lapide animali*, which has puzzled and has been called in queftion by many fucceeding chemifts. The experiment is this: two or three ounces of hartfhorn are to be diffolved in nitro-muriatic acid, in which a drachm of gold-leaf is afterwards to be diffolved, by digeftion in a glafs cucurbit: the fluid being diftilled off, the refidue is to be fufed quickly in an open crucible in a forge fire: the upper part will be found changed into a black fcoria, beneath which the gold is found rendered white and brittle like regulus of antimony.

§ 7. *Alloys of Gold.*

Mr. Hatchett's valuable experiments on the alloys of gold as detailed in the Philofophical Tranfactions for 1803, have been confulted for moft of the facts in the prefent fection; thofe which have been obtained from other fources, will be noticed accordingly.

Arfenic, on account of its volatility, can be combined with gold only in fmall proportions. If the mixture is attempted to be made by projecting metallic arfenic on gold in fufion in an open crucible, the arfenic according to the quantity ufed, will be either entirely or in great part diffipated, and the gold in confequence will remain entirely unaltered or rendered more or lefs brittle. If a fmall crucible containing gold be inferted into a larger one containing arfenic, and an inverted crucible be luted on by way of a cover, and the apparatus be heated ftrongly in a wind furnace, the arfenic will be raifed in vapour, and the gold being fufed in this arfenicated atmofphere, will combine with a fmall portion of it. The alloy hence refulting is of a grey colour, a coarfe granular fracture, and very brittle. A heat equal to that of

[q] Phil. Trans. 1797. p. 219.

[r] Memoires I. p. 266. II. p. 25.

melting gold is by no means neceſſary to effect this combination, for if a plate of gold is merely brought to a full red heat in an atmoſphere loaded with arſenic, this latter will unite ſuperficially with the gold, and the alloy hence reſulting being very fuſible, will trickle in drops from the plate, till the whole of it is thus arſenicated. This alloy is ſcarcely decompoſable by mere heat, and at a high temperature the arſenic that is driven off, carries a conſiderable proportion of gold along with it.

If antimony is mixed by fuſion with either fine or ſtandard gold in the proportion of even $\frac{1}{8}$ of a grain to the ounce ($\frac{1}{1\,9\,2\,0}$ of the whole maſs) the reſulting compound is brittle, has a cloſe granular fracture, with hardly any metallic luſtre, and its bulk will be found to be remarkably greater than would be deduced from the mean ſpecific gravity of its ingredients.

Zinc forms with gold an alloy of a braſs-yellow colour; in other reſpects its action on gold is very analogous to that of arſenic; when projected in ſmall quantity on melted gold, it is entirely volatilized; in the ſtate of vapour it combines with gold and renders it brittle. Fine braſs added to gold in the proportion of $\frac{1}{24}$ forms a pale yellow brittle alloy, with a coarſe granular fracture. The ſpecific gravity of gold and zinc is ſomewhat greater than the calculated mean, where it forms $\frac{1}{12}$ of the maſs. According to Hellot,[r] an alloy of three parts of zinc, and one of gold, is ſomewhat malleable: and equal parts of the two metals form a compound which though brittle, is ſuſceptible of a very high poliſh, and is but little liable to tarniſh.

Cobalt mixed with ſtandard gold, in the proportion of 4 grains to an ounce, renders the colour ſomewhat paler, and induces a ſlight degree of brittleneſs, but does not materially alter the ſpecific gravity. When mixed with fine gold in the proportion of 38 grains to the ounce, the reſult is a pale yellow alloy, very brittle, and with an earthy fracture.

Nickel alloyed with gold in the proportion of 38 grains in the ounce, produces an alloy of the colour of fine braſs, with a coarſe grained earthy fracture, and very brittle: its ſpecific gravity is leſs than the mean. If the nickel is reduced to eight grains in the ounce of ſtandard gold, the alloy is only ſlightly brittle; and with 4 grains of nickel, the mixture continues perfectly ductile.

Gold may be alloyed with manganeſe by calcining the black oxyd of this metal repeatedly with oil in a covered crucible, and then expoſing it to a very high heat in contact with gold. The colour of the alloy thus produced is a reddiſh-grey; it is capable of receiving a brilliant luſtre like ſteel; it is exceſſively hard, and is ſo far poſſeſſed of ductility, as to be in ſome meaſure flattened by the hammer before it breaks. The proportion of manganeſe thus combined is from $\frac{1}{8}$ to $\frac{1}{4}$ of the alloy. The gold in this mixture defends the manganeſe not only from being oxydated by the air, but alſo protects it from the action of all thoſe acids in which gold itſelf is inſoluble. By long expoſure to a high heat with acceſs of air, the manganeſe riſes to the ſurface of the gold, where it becomes oxydated, leaving this latter metal behind quite pure. Theſe two metals may in like manner be ſeparated by cupellation with lead, or by ſolution in nitric acid, if the alloy has previouſly been quarted with ſilver.

If gold is mixed with biſmuth, in the proportion of 38 grains to the ounce, the reſult is an alloy of a pale greeniſh yellow, exceſſively brittle, and exhibiting a fine grained earthy fracture: its ſpecific gravity is ſomewhat greater than the mean. If ſtandard gold is alloyed even with $\frac{1}{4}$ of a grain of biſmuth in the ounce, the mixture, although in colour and texture reſembling ſtandard gold, is yet perfectly brittle. So great is the liability of gold to be affected by biſmuth, that if it comes in contact even with the fumes of this metal, and that not in cloſe veſſels, its ductility is entirely deſtroyed.

If lead is melted with gold in the proportion of 38 grains in the ounce, the alloy though externally reſembling pale fine gold, is as brittle as glaſs; is of a pale brown colour internally; is wholly deſtitute of metallic luſtre, and has a fine-grained porcellanous appearance; its ſpecific gravity is a little leſs than the mean. When the proportion of lead is reduced to $\frac{1}{4}$ of a grain in the ounce, the alloy is ſtill perfectly brittle; and the fumes of this metal are nearly as prejudicial to the ductility of the gold as thoſe of biſmuth.

Tin when mixed with gold in the proportion of 38 grains in the ounce, forms an alloy of a pale yellowiſh-grey colour, with a fine ſomewhat earthy fracture; it may be bent without breaking, but is very little ductile: its ſpecific gravity is conſiderably greater than the mean of the ingredients. An alloy compoſed of 19 grs. tin, 19 grs. copper, and the remainder of the ounce gold, has a coarſe grained earthy fracture, and is conſiderably more brittle than if no copper had been made uſe of. An alloy com-

[r] Lewis.

poſed of 442 grs. in the ounce gold, 30 copper, and 8 tin, was of a ſomewhat paler colour than ſtandard gold, but was perfectly ductile, and very ſoft. When it was expoſed to a cherry-red heat, (10° Wedgw.) the ſurface began to be roughened by bubbles or bliſters, then the bar began to warp on the edges, and laſtly, when the whole of the tin diffuſed through the alloy, might be ſuppoſed to be in fuſion, the bar fell by its own weight from the ſupporters on which it was placed, in a rough, dark coloured maſs, having ſcarcely any appearance of a metal: it recovered however its luſtre and ſome tenacity by being hammered on a poliſhed anvil.[t]

Iron, either in the ſtate of bar iron, caſt iron, or ſteel, may be combined with gold to the amount of 38 grains, and probably much more, in the ounce, without in the leaſt degree impairing its ductility: the colour of the alloy is pale yellowiſh grey, approaching to dull white; it is conſiderably harder than ſtandard gold, and its ſpecific gravity is ſomewhat leſs than the mean of its conſtituent ingredients.

Platina and gold, when the proportion of the former amounts to 38 grains in the ounce, compoſe an alloy of a yellowiſh white colour, like tarniſhed ſilver, perfectly ductile, but much harder and conſiderably more elaſtic than ſtandard gold. If to the foregoing alloy, the ſtandard proportion of copper is added, the compound becomes of a pale dull yellow, and its ductility is ſomewhat diminiſhed.

When gold is rendered ſtandard by copper, that is, when the proportion of this laſt amounts to 38 grains in the ounce, the reſulting alloy is of a deep yellow colour inclining to red; is harder than pure gold, but perfectly ductile. Its ſpecific gravity is leſs than that of the mean of its ingredients in a remarkable degree. Equal parts of copper and gold alſo form a perfectly ductile alloy. It is not however every kind of reputedly pure copper which can ſafely be uſed for alloying gold: even the Swediſh dollar copper occaſionally renders the gold with which it is mixed, as brittle as glaſs: this appears to be owing to the lead and antimony which moſt copper contains, and which though not in ſufficient quantity to affect in any material degree the ductility of the copper itſelf, are fully adequate to deſtroy the ductility of the gold with which they are mixed; ſince no more than $\frac{1}{192}$ of either of theſe metals is enough for this purpoſe, as we have already mentioned.

Silver may be alloyed with gold in all proportions, and occaſions hardly any perceptible alteration of the ductility, hardneſs, or mean ſpecific gravity; the colour of the maſs becomes paler, exactly as the quantity of the ſilver is increaſed.

For the combination of gold with mercury, ſee MERCURY.

The chief uſe of gold is in coin: it is alſo applied in maſs, in thread, and in leaf to many purpoſes of luxury and ornament. The purple oxyd is employed as a material for colouring glaſs and porcelain. The old chemiſts vaunted greatly its medical effects, but it has long ſince diſappeared from every European pharmacopœa.

GOLD-BERYL. See CHRYSOBERYL.

GOLDEN SULPHUR OF ANTIMONY. See ANTIMONY.

GRADUATION of Saline Liquors. A method of concentrating weak ſaline ſolutions, by pouring them through a heap of faggots and expoſing them in this divided ſtate to a free current of air. For further particulars, ſee MURIAT *of Soda*.

GRAINE D'AVIGNON. See AVIGNON Berry.

GRAMMATIT. See TREMOLITE.

GRANAT. See GARNET.

GRANATIT. See STAUROLITE.

GRANITE. *Granite.* Fr. *Granit.* Germ.

Granite is a rock eſſentially compoſed of felſpar, quartz, and mica, in grains or cryſtals of various magnitude. The parts of which it conſiſts adhere to each other by the mere attraction of aggregation, and not by any paſte or cement which binds them together, by which character this rock is diſtinguiſhed from porphyry, as it is from gneiſs by the abſence of the ſlaty or ſchiſtoſe texture. Felſpar is for the moſt part the predominating ingredient, and is not unfrequently in regular cryſtals; its colour is either milk-white, yellowiſh-white, honey-yellow, or fleſh-red; when the cryſtals are very large they ſometimes contain angular fragments of quartz, which from their reſemblance to the Perſepolitan characters, have obtained for this variety, among the French, the name of *pierre graphique:* in other varieties the felſpar is found more or leſs deprived of its cryſtalline texture, and converted into indurated porcelain clay. The quartz in granite though ſeldom actually in cryſtals, poſſeſſes the tranſparency, fracture and other external characters that denote the cryſtalline texture; its colour is moſtly a ſmoak yellow, of different degrees of intenſity; ſometimes though rarely it occurs of a fine granular texture and a ſnow-white colour. The mica

[t] Bingley in Phil. Tranſ. for 1803, p. 75.

is in plates very various as to ſize, and in colour ſilvery white, ſmoak-brown, black, and green.

Granite (eſpecially the large-grained which is generally eſteemed to belong to the earlieſt formation) is often diſpoſed in very thick and extenſive beds or ſtrata, hence it is found to ſplit much eaſier in ſome directions than in others. The hardneſs and compactneſs of this rock vary extremely according to the perfection or tendency to decompoſition of the felſpar which it contains. The fleſh-coloured can hardly ever be wrought without the help of gunpowder, but the white is often ſo rifty as to render blaſting impracticable, at the ſame time that it ſtill remains very difficult to work by the pick and other common inſtruments. Cavities ſometimes of conſiderable magnitude are occaſionally found in granite, lined with calcareous ſpar and colourleſs or amethyſtine cryſtals of quartz; and in the ſubſtance of the rock itſelf are contained various minerals beſides the three of which it is eſſentially compoſed. When the proportion of mica is conſiderable, and the rock begins to paſs into gneiſs, it ſometimes contains ſmall garnets; when on the other hand the granite is very large grained, it abounds with cryſtals of black ſchorl. The other extraneous ſubſtances that it contains are beryl, hornblende, ſteatite, ſemi-opal, heavy-ſpar, and bitterſpath. It does not abound in metallic ores; hæmatite, tin-ſtone, galena, native ſilver, earthy cobalt, molybdena, biſmuth and copper pyrites, have been found in granite, though in no great quantity.

Granite is reckoned the oldeſt of the primitive rocks, and is found in almoſt all the great mountainous chains, ſuch as the Alps, the Pyrennees, the Crapack or Carpathian mountains, and the Norwegian mountains. In Britain, granite is found abundantly in the Grampians, and on the eaſt coaſt of Scotland between the firths of Tay and Murray, at Portſoy in particular are vaſt quantities of Pierre graphique: at Mount Sorrel, in Leiceſterſhire, is a low range of granite, and a little is to be met with in Shropſhire. Wales contains none, with the exception of a narrow bank or two in Angleſey, but in Cornwall and the north of Devonſhire, it is the common rock of the country.

The uſes of granite are conſiderable; it is much employed in Scotland as a building material; it is the moſt durable ſubſtance that can be uſed for paving ſtreets; and the ancients, eſpecially the Egyptians, formed of it ſtatues, obeliſks, ſarcophagi, and various other works of art.

GRANITE of Corſica. See MANDLSTEIN.

GRANULATION.

The proceſs by which a metal is reduced into grains is called granulation. This is for the moſt part effected by melting the metal, and then pouring it in a very ſlender ſtream into cold water. As ſoon as the metal touches the water it divides into drops, which have a tendency to a ſpherical ſhape, and are more or leſs perfect according to the thinneſs of the ſtream, the heighth from which it falls, and the temperature both of the water and the metal. Tin, and ſome others of the moſt fuſible metals, may be reduced to much finer grains than can be effected in the uſual way, by pouring it when melted into a wooden box ſmeared on the inſide with chalk, and ſhaking it violently before it has time to become ſolid. By this means tin is reduced to a fine powder; and there is no doubt but that the leſs fuſible metals might likewiſe be ſo pulverized by a ſimilar manipulation.

GRAPHITE, or Plumbago. See COAL. *Species* ix.

GRAUSTEIN. See TRAP.

GRAUWACKE.

This name, for which we have no correſponding Engliſh term, is employed by the German mineralogiſts to denote a ſpecies of rock belonging to the more recent of the Tranſition claſs, and of which there are two very diſtinct varieties.

Common Grauwacke is compoſed of grains of quartz, ſiliceous ſchiſtus and ſlate or argillite, agglutinated by an argillaceous cement; the grains vary from the ſize of a pin's head to that of a hazlenut.

Slaty Grauwacke, is a ſimple ſchiſtoſe rock, which at firſt ſight might be confounded with argillite, but upon a nearer inſpection will be found to differ in colour which is of a dirty grey, in being entirely deſtitute of luſtre, in containing ſpangles of mica, which true ſlate never does, in its geological ſituation, and in its being never divided by beds of chlorite ſlate or Whetſtone ſlate.

Both varities of grauwacke are traverſed by veins of quartz in various directions, and contain occaſionally ſhells and vegetable remains: they never contain beds of other kinds of rock. They are never diſtinctly ſtratified, but their inclination is never parallel with that of the rock on which they reſt.

Grauwacke contains ſometimes beds of glance coal, and is rich in metallic ores; the mines of lead and ſilver in the Hartz, and ſome of the gold-mines in Tranſylvania, are in this rock.

GREEN EARTH.[a] *Terre verte.* Broch. *Grünerde.* Emmerl.

The colour of this mineral is celandine green of various ſhades, paſſing into mountain and blackiſh-green, rarely into olive-green. It occurs in maſs, in angular or globular pieces, or diſſeminated, or as a ſuperficial covering to balls of agate, or lining the empty cavities in amygdaloid. Its fracture is fine grained earthy, paſſing into flat conchoidal; it has no luſtre; it breaks into indeterminate blunt-edged fragments. It gives a ſhining ſtreak; is ſmooth and ſomewhat unctuous to the touch; is very ſoft; opake; adheres ſlightly to the tongue; is light and eaſily frangible.

When expoſed to the blow-pipe it blackens, but does not melt by itſelf: with borax it gives a browniſh-black opake glaſs; when immerſed in water it abſorbs a conſiderable quantity, but does not break down in it, or become plaſtic.

It is found wherever amygdaloid occurs, as in Saxony, Bohemia, Monte Baldo near Verona, Scotland, &c. When of a good colour it is made ſome uſe of by painters.

GRUNERDE. See GREEN EARTH.

GRUNSTEIN. See TRAP.

GUM-ELASTIC. See CAOUTCHOUC.

GUM-MUCILAGE. See MUCILAGE. *(Vegetable.)*

GUM-RESIN.

Theſe are for the moſt part the juices of various trees of tropical climates, which ooze out from natural cracks in the bark, or artificial inciſions, and harden by the ſun and air into irregular roundiſh maſſes. The gum-reſins therefore are the juices of the reſpective plants as nearly as poſſible in their natural ſtate, and they retain the ſenſible properties of ſmell and taſte for a very great length of time. A ſimilar juice, but inferior in quality, may alſo be obtained from ſome of them by macerating in water the entire vegetable, or part of the vegetable that yields it, and evaporating the water to an extract, but this is very ſeldom practiſed.

The gum-reſins are almoſt excluſively employed in medicine, and only a very few of them have engaged the attention of chemiſts. Though they agree in thoſe leading characters which conſtitute a *gum-reſin*, there is a vaſt difference in the compoſition of the ſeveral ſpecies when examined chemically, and they paſs almoſt by imperceptible gradations either into the pure reſins, or into the extracts and gummy mucilages.

Of the moſt important gum-reſins may be enumerated, myrrh, galbanum, aſafœtida, ammoniacum, olibanum, ſagapenum, and perhaps opium. The chemical analyſis of theſe and others where it preſents any important reſults, will be given under the reſpective articles.

The general or characteriſtic properties of a *gum-reſin* are (as its name imports) ſuch as would be produced by a natural mixture of gum and reſin. To the reſinous part they chiefly owe the property of burning with much flame, melting in drops by the heat; of giving by diſtillation a large portion of volatile oil and ſome ammonia. To the gummy part they owe their partial ſolubility in water, ſo that when rubbed with this fluid they form an emulſion, generally whitiſh, which remains a conſiderable time turbid, and even when by reſt the gum reſin has again ſubſided, the clear liquor always retains ſome of the taſte and ſmell of the ſubſtance employed.

Some of the gum-reſinous juices are alſo mixed with a kind of EXTRACT, or a coloured and bitter ſubſtance ſoluble in water and alcohol, and alſo TAN is very commonly united to them. On the whole the term Gum-Reſin is more properly a pharmaceutical than a chemical diſtinction.

GUNPOWDER. *Poudre a Canon.* Fr. *Das Schieſspulver.* Germ.

Is a mechanical mixture of nitre, charcoal, and ſulphur, the explоſive powers of which are familiar to every one. The method of manufacture is extremely ſimple, but conſiderable precautions are neceſſary in the ſelection of pure and good materials, in enſuring a very intimate admixture, and in avoiding any ſtrong colliſion or any other event which might produce fire, and thus kindle the powder, and be productive of the moſt dreadful accidents.

The actual mode of making gunpowder in England (and in all countries it is eſſentially the ſame) cannot be better deſcribed than from the account given by Mr. Coleman, of the Royal Powder Mills of Waltham Abbey, about twelve miles north of London.[a] The ingredients of gunpowder are taken in the following proportion, namely, 75 of ſaltpetre, 15 of charcoal, and 10 of ſulphur. The ſaltpetre uſed is almoſt entirely that which is imported from the Eaſt Indies, which comes over in the rough ſtate mixed with earthy and other ſalts, and is refined (in the manner deſcribed under the article NITRAT *of Potaſh*) by ſolution, evaporation, and cryſtallization. After this it is fuſed in a moderate heat, ſo as to expell all the pure water,

[a] Emmerl. Jameſon, Brochant. [a] Phil. Mag. Vol. ix.

but none of the acid, and is then fit for uſe. The great uſe of refining the nitre is to get rid of the deliqueſcent ſalts, which by rendering the powder made of it liable to become damp by keeping, would moſt materially impair its goodneſs. The ſulphur uſed is imported from Italy and Sicily, where it is collected in its native ſtate in abundance. It is refined by melting and ſkimming, and when very impure, by ſublimation. It ſhould ſeem that the Engliſh ſulphur, extracted in abundance from ſome of the copper and other mines, is too impure to be economically uſed for gunpowder, requiring expenſive proceſſes of refining.

The charcoal formerly uſed in this manufacture near London (and ſtill uſed in moſt parts of the world) was prepared in the uſual way of charring wood, piles being formed of it and covered with ſods or fern, and ſuffered to burn with a ſlow ſmothering flame. This method however cannot with any certainty be depended on to produce charcoal of an uniformly good quality, and therefore a moſt eſſential improvement has been adopted in this country, to which the preſent ſuperior excellence of Engliſh powder may be in a good meaſure attributed, which is, that of encloſing the wood, cut into billets about nine inches long, in iron cylinders placed horizontally, and burning them gradually to a red heat, continuing the fire till every thing volatile is driven off, and the wood is compleatly charred. But as the pyroligneous acid, the volatile product of the wood heated *per ſe*, is of uſe in manufacture, it is collected by pipes paſſing out of the iron cylinder, and dipping into caſks where the acid liquor condenſes. This acid is uſed in ſome parts of calico-printing, chiefly as the baſis of ſome of the iron liquors and mordants for dark-coloured patterns. The wood before charring is barked. It is generally either alder or willow, or dog-wood, but there does not appear any certain ground for preferring one wood to another provided it be fully charred.

The above three ingredients being prepared, they are firſt ſeparately ground to fine powder, then mixed in the proper proportions, after which the mixture is fit for the important operation of thoroughly incorporating the component parts in the mill. A powder mill is a ſlight wooden building, with a boarded roof, ſo that in the event of any moderate exploſion, the roof will fly off without difficulty, and the ſudden expanſion will thus be made in the leaſt miſchievous direction. Stamping mills were formerly uſed here, which conſiſted ſimply of a large wooden mortar, in which a very ponderous wooden peſtle was made to work, by the power of men, or horſes, or water, as convenience directed. Theſe performed the buſineſs with very great accuracy, but the danger from over-heating was found to be ſo great, and the accidents attributable to this cauſe were ſo numerous, that ſtamping mills have been moſtly diſuſed in large manufactures, and the buſineſs is now generally performed by two ſtones placed vertically, and running on a bed-ſtone or trough.

The mixed ingredients are put on this bed-ſtone in quantities not exceeding 40 or 50 pounds at a time, and moiſtened with juſt ſo much water, as will bring the maſs in the grinding to a conſiſtence conſiderably ſtiffer than paſte, in which it is found by experience that the incorporation of the ingredients goes on with the moſt eaſe and accuracy. Theſe mills are worked either by water or horſes.

The compoſition is uſually worked for about ſeven or eight hours before the mixture is thought to be ſufficiently intimate, and even this time is often found by the inferior quality of the powder to be too little. The fine powder manufactured at Battle in Suſſex, is ſtill however made in large mortars or ſtamping mills, in the old way, with heavy lignum-vitæ peſtles. Only a very few pounds of the materials are worked at a time.

The compoſition is then taken from the mills and ſent to the *corning-houſe*, to be corned or grained. This proceſs is not eſſential to the manufacture of perfect gunpowder, but is adopted on account of the much greater convenience of uſing it in grains than in fine duſt. Here the ſtiff paſte is firſt preſſed into hard lumps, which are put into circular ſieves with parchment bottoms, perforated with holes of different ſizes, and fixed in a frame connected with a horizontal wheel. Each of theſe ſieves is alſo furniſhed with a *runner* or oblate ſpheroid of lignum vitæ, which being ſet in motion by the action of the wheel, ſqueezes the paſte through the holes of the parchment bottom, forming grains of different ſizes. The grains are then ſorted and ſeparated from the duſt by ſieves of progreſſive dimenſions.

They are then *glazed* or hardened, and the rough edges taken off, by being put into caſks, filling them ſomewhat more than half-full, which are fixed to the axis of a water-wheel, and in thus rapidly revolving the grains are ſhaken againſt each other and rounded, at the ſame time receiving a ſlight gloſs or glazing.

Much duſt is alſo ſeparated by this proceſs. The glazing is found to leſſen the force of the powder from a fifth to a fourth,[b] but the powder keeps much better when glazed, and is leſs liable to grow damp.

The powder being thus corned, duſted and glazed, is ſent to the ſtove-houſe and dried, a part of the proceſs which requires the greateſt precautions to avoid exploſion, which in this ſtate would be much more dangerous than before the intimate mixture of the ingredients.

The ſtove-houſe is a ſquare apartment, three ſides of which are furniſhed with ſhelves or caſes, on proper ſupports, arranged round the room, and the fourth contains a large caſt-iron veſſel called a *gloom*, which projects into the room, and is ſtrongly heated from the outſide, ſo that it is impoſſible that any of the fuel ſhould come in contact with the powder. For greater ſecurity againſt ſparks by accidental friction, the glooms are covered with ſheet copper, and are always cool when the powder is put in or taken out of the room. Here the grains are thoroughly dried, loſing in the proceſs all that remains of the water added to the mixture in the mill, to bring it to a working ſtiffneſs. This Mr. Coleman finds to be from three to five parts on 100 of the compoſition. The powder when dry is then compleat.

The government powder for ordnance of all kinds as well as for ſmall arms, is generally made at one time, and always of the ſame compoſition, the difference being only in the ſize of the grains as ſeparated by the reſpective ſieves.

A method of drying powder by means of ſteam-pipes running round and croſſing the apartment has been tried with ſucceſs: by it all poſſibility of an accident from over-heating is prevented. The temperature of the room when heated in the common way by a gloom-ſtove is always regulated by a thermometer hung in the door of the ſtoves.

The ſtrength of the powder is ſometimes injured by being dried too haſtily and at too great a heat, for in this caſe ſome of the ſulphur ſublimes out (which it will do copiouſly at a leſs heat than will inflame the powder) and the intimate mixture of the ingredients is again deſtroyed. Beſides if dried too haſtily, the ſurface of the grain hardens leaving the inner part ſtill damp.

Mr. Coleman deduces from experiment the following inferences, namely: that the ingredients of gunpowder only pulverized and mixed have but a very ſmall exploſive force: that gunpowder granulated after having been only a ſhort time on the mill, has acquired only a very ſmall portion of its ſtrength, ſo that its perfection abſolutely depends on very long-continued and accurate mixture and incorporation of the ingredients: that the ſtrength of gunpowder does not depend on granulation, the duſt that ſeparates during this proceſs being as ſtrong as the clean grains: that powder undried, is weaker in every ſtep of the manufacture than when dried: and laſtly, that charcoal made in iron cylinders in the way already mentioned, makes much ſtronger powder than common charcoal. This laſt circumſtance is of ſo much conſequence, and is ſo fully confirmed by experience, that the charges of powder now uſed for cannon of all kinds have been reduced one-third in quantity, when this kind of powder is employed.

In barrelling powder, particular care muſt be taken to avoid moiſture, and this buſineſs is alſo generally reſerved for dry weather.

When powder is only a little damp, it may be reſtored to its former goodneſs merely by ſtoving, but if it has been thoroughly wetted, the nitre (the only one of the ingredients ſoluble in water) ſeparates more or leſs from the ſulphur and charcoal, and by again cryſtallizing cakes together the powder in whitiſh maſſes which are a looſe aggregate of grains covered on the ſurface with minute efflorescences of nitre. In this caſe the ſpoiled powder is put into warm water entirely to extract the nitre, and the other two ingredients are ſeparated by ſtraining and thrown away.

The ſpecific gravity of gunpowder is eſtimated by Count Rumford[c] to be about 1.868.

The ſtrength and goodneſs of powder is judged of in ſeveral ways, namely, by the colour and feel, by the flame when a ſmall pinch is fired, and by meaſuring the actual projectile force by the *eprouvette*, and by the diſtance to which a given weight will project a ball of given dimenſions under circumſtances in all caſes exactly ſimilar.

When powder rubbed between the fingers eaſily breaks down into an impalpable duſt, it is a mark of containing too much charcoal, and the ſame if it readily ſoils white paper when gently drawn over it. The colour ſhould not be abſolutely black, but is preferred to be more of a dark blue with a little caſt of red. The trial by firing is thus managed; lay two or three ſmall heaps of about a dram each on clean writing paper, about three or four inches aſunder, and

[b] Napier, Iriſh Tranſactions. [c] Eſſays.

fire one of them by a red-hot iron wire: if the flame aſcends quickly with a good report, ſending up a ring of white ſmoke, leaving the paper free from white ſpecks and not burnt into holes, and if no ſparks fly off from it, ſetting fire to the contiguous heaps, the powder is judged to be very good, but if otherwiſe, either the ingredients are badly mixed or impure.

The common eprouvettes or powder-triers are ſmall ſtrong barrels, in which a determinate quantity of the powder is fired, and the force of expanſion meaſured by the action excited on a ſtrong ſpring or a great weight.

Another method often adopted is to fire a very heavy ball from a ſhort mortar with a given weight of the powder and to find the range of projection.[d] The French eprouvette for government powder is a mortar of 7 inches (French) in calibre, which with three ounces of powder ſhould throw a copper globe of 60 lbs. weight to the diſtance of 300 feet. No powder is admitted which does not anſwer this trial.[e]

Both theſe methods have been objected to, the former becauſe the ſpring is moved by the inſtantaneous ſtroke of the flame and not by its continued preſſure, which is ſomewhat different; and the other on account of the tedioufneſs attending its uſe when a large number of barrels of powder are to be tried. Another method which unites accuracy with diſpatch, is to ſuſpend a ſmall cannon as a pendulum, to fire it with powder only, and to judge of the force of exploſion by that of the recoil, which in this circumſtance is a greater or leſs arc of a circle. That which Dr. Hutton employs on this principle is a ſmall cannon about one inch in the bore, the charge of which is two ounces of powder.

The cauſe and meaſure of the exploſive force of fired gunpowder has been much inveſtigated. It is generally allowed to be chiefly owing to the ſudden generation of a quantity of gas or elaſtic vapour, the chemical conſtitution of which will be preſently mentioned.

To determine the elaſticity and quantity of this elaſtic vapour produced from a given quantity of powder, Mr. Robins[f] premiſes that its elaſticity is equally encreaſed by heat and diminiſhed by cold as that of common air (which is confirmed by Mr. Dalton's late experiments), and conſequently its weight is the ſame with the weight of an equal bulk of air at the ſame elaſticity and temperature. Hence, and from direct experiments, he concludes that the elaſtic fluid produced by the firing of gunpowder is nearly $\frac{1}{210}$ of the weight of the powder itſelf, which expanded to the rarity of common air is about 244 times the bulk of the powder. Hence it would follow that the mere converſion of confined powder into elaſtic vapour would exert againſt the ſides of the containing veſſel an expanſive force 244 times greater than the elaſticity of common air, or in other words, than the preſſure of the atmoſphere. But to this is to be ſuperadded all the increaſe of expanſive power produced by the heat generated, which is certainly very intenſe, though its exact degree cannot be aſcertained. Suppoſing it to be equal to the full heat of red-hot iron, this would increaſe the expanſion of common air (and alſo of all gaſſes) about four times, which in the preſent inſtance would increaſe the 244 to nearly 1000, ſo that in a general way it may be aſſumed that the expanſive force of cloſely confined powder at the inſtant of firing is 1000 times greater than the preſſure of common air: and as this latter is known to preſs with the weight of $14\frac{3}{4}$ pounds on every ſquare inch, the force of exploſion of gunpowder is 1000 times this, or, 14750 lb. or about ſix tons and a half on every ſquare inch. This enormous force, however, diminiſhes in proportion as the elaſtic fluid dilates, being only half the ſtrength when it occupies a double ſpace, one-third of the ſtrength when in a triple ſpace, and ſo on.

Mr. Robins found that the ſtrength of powder is the ſame in all variations of the denſity of the atmoſphere, but not ſo in every ſtate of moiſture, being much impaired by a damp air, or with powder damped by careleſs keeping or any other cauſe, ſo that the ſame powder which will diſcharge a bullet at the rate of 1700 feet in a ſecond in dry air, will only propel it about 1200 feet when the air is fully moiſt, and a ſimilar difference holds between dry and moiſt powder.

A very conſiderable variation is found in the proportions of the ingredients of the powder of different nations and different manufactories, nor is it exactly aſcertained whether there is any one proportion which ought always to be adhered to and for every purpoſe. The government powder made in this country is the ſame for cannon as for ſmall arms, the difference being only in the ſize of the grains, but in France it appears that there were formerly ſix different ſorts manufactured, namely, the ſtrong and the weak cannon powder, the ſtrong and the weak muſquet powder, and the ſtrong and the weak piſtol powder. The following are the propor-

[d] Encycl. Arts and Metiers. [e] Hutton's Mathemat. Dict. [f] A Treatiſe on Gunnery, or Hutton's Dicty.

tions in each, though the reaſon of this nicety of diſtinction is not very obvious. For the ſtrong cannon powder the nitre, ſulphur, and charcoal were in the proportions of 100 of the firſt, 25 of the ſecond, and 25 of the third: for the weak cannon powder, 100, 20, and 24: for the ſtrong muſquet powder, 100, 18, and 20; for the weak, 100, 15, and 18: for the ſtrong piſtol powder, 100, 12, and 15; for the weak, 100, 10, and 18.

The Chineſe powder appears by the analyſis of Mr. Napier to be nearly in the proportions of 100 of nitre, 18 of charcoal, and 11 of ſulphur. This powder which was procured from Canton was large-grained, not very ſtrong, but hard, well-coloured, and in very good preſervation.

The ſulphur is not (properly ſpeaking) a neceſſary ingredient in gunpowder, ſince nitre and charcoal alone well mixed will explode, but the uſe of the ſulphur ſeems to be to diffuſe the fire inſtantaneouſly through the whole maſs of powder. But if the following experiments are correct, it ſhould ſeem that the advantage gained by uſing ſulphur in increaſing the force of exploſion only applies to ſmall charges, but in quantities of a few ounces the exploſive, or at leaſt the *projecting* force of powder without ſulphur, is full as great as with ſulphur.

The following are a few out of many trials made at the Royal Manufactory at Eſſone, near Paris, in the year 1756, to determine the beſt proportions of all the ingredients. Of powder made with nitre and charcoal alone, 16 of nitre and 4 of charcoal was the ſtrongeſt, and gave a power of 9 in the eprouvette. With all three ingredients, 16 of nitre, 4 of charcoal, and 1 of ſulphur, raiſed the eprouvette to 15, and both a leſs and a greater quantity of ſulphur produced a ſmaller effect. Then diminiſhing the charcoal, a powder of 16 of nitre, 3 of charcoal, and 1 of ſulphur gave a power of 17 in the eprouvette, which was the higheſt produced by any mixture. This laſt was alſo tried in the mortar-eprouvette againſt the common proof powder, and was found to maintain a ſmall ſuperiority. The powder made without ſulphur in the proportions above indicated was alſo tried in the mortar-eprouvette, and with the following ſingular reſult: when the charge was only two ounces it projected a ſixty pound copper ball 213 feet, and the ſtrongeſt powder with ſulphur projected it 249 feet; but in a charge of three ounces, the former projected the ball 475 feet and the latter only 472 feet: and on the other hand the great inferiority of force in the ſmaller eprouvette of the powder without ſulphur has been juſt noticed.

Gunpowder is reckoned to explode at about 600° Fahr. but if heated to a degree juſt below that of faint redneſs, the ſulphur will moſtly burn off, leaving the nitre and charcoal unaltered. The gaſſes produced by the exploſion of powder have not been analyzed with accuracy ſince the diſcovery of all the varieties of gaſſes with the baſis of carbon, but they are certainly carbonic acid, ſulphureous acid gas, and carburetted hydrogen. The reſidue is chiefly a ſulphuret of potaſh formed by a part of the ſulphur uniting with ſome of the alkali of the nitre, and hence the hepatic ſmell of a foul and damp gun-barrel.

The analyſis of gunpowder performed with ſufficient accuracy for moſt practical purpoſes is very eaſy and ſimple, but an abſolutely accurate analyſis is more difficult. The uſual way is firſt to boil the powder with three or four times its weight of water, edulcorating it with more hot water till no ſaline taſte remains. This extracts the nitre only, the quantity of which may be either aſcertained by drying the reſidue and eſtimating as nitre all the loſs of weight, or more directly by evaporating the watery ſolution. If the reſidue, conſiſting of the ſulphur and charcoal, is now ſpread on a earthen plate of any kind and ſlowly heated, the ſulphur takes fire and burns off gradually, whilſt the charcoal remains untouched, when the heat is kept down ſufficiently. Beaume found however that when all the ſulphur is expelled which will be driven off in this heat, a certain portion will ſtill remain and will not burn away at a lower temperature than will conſume the charcoal, ſo that to the laſt the burning reſidue will ſmell ſtrongly ſulphureous. This retained portion of ſulphur he finds by the reſults of many other experiments to be very uniformly about one twenty-fourth part of the whole ſulphur employed, whence for all common purpoſes an adequate correction may be made by eſtimating that the ſlow weak combuſtion of the reſidue, after the nitre has been got out, deſtroys only $\frac{1}{24}$ of the ſulphur inſtead of the whole. On trying to ſeparate them by an alkaline ſolution, he found ſome of the ſulphur to remain undiſſolved and ſtill adhering to the charcoal. The way to enſure perfect accuracy in analyſis would be firſt to ſeparate the nitre by hot water, then to acidify all the ſulphur by the nitric acid, to diſſolve and to precipitate it by a ſolution of nitrat or muriat of barytes, and from the known conſtituents of this ſalt to find

the quantity of ſulphur, whilſt the charcoal here remains perfectly untouched.

The diſcovery of the aſtoniſhing fulminating property of the ſalts with the OXYMURIATIC acid led ſeveral chemiſts to the idea of ſubſtituting the oxymuriat of potaſh to the nitre in the manufacture of gunpowder, and experiments have been made on a ſufficient ſcale to ſhew that this gunpowder far exceeds the common powder in energy of explosive power. The oxymuriats however appear to act in a different manner from the mixtures with nitre, and to exert all their power extremely ſuddenly and in a very ſmall ſpace, ſo as to deſtroy every ſubſtance in immediate contact with them at the time of explosion, but to be inferior in projectile force to common gunpowder. All the explosive compounds with the oxymuriats have alſo the very dangerous property of exploding with very moderate friction, and hence they have never been employed in the large way.

GYPSUM. [a]

Of the mineral ſpecies there are two families characterized by the preſence or abſence of water of cryſtallization.

1ſt FAMILY. Affords by diſtillation about 20 per cent. of water; and at a temperature below a red heat becomes an opake white powder.

1. Subſpecies. SELENITE. *Chaux Sulfatée.* Hauy. *Broad-foliated Gypſum.* Kirw. *Sélénite,* Broch. *Selenite.* Jameſon. *Spathiger Gips.* Emmerl. *Fraueneis.* Wern.

It is either colourleſs, or yellowiſh and greyiſh white, ſmoak-grey; wax, honey, and ochre-yellow and yellowiſh-brown: it alſo not unfrequently exhibits an irideſcent play of colours.

It occurs in maſs or cryſtallized. The primitive form of its cryſtals is a ſtrait quadrangular priſm, the baſes of which are oblique parallelograms, and the angles = 113° : 7′ : 48″ and 66° : 52′ : 12″. The chief varieties of cryſtallization that it is found to undergo are the following.

1. A thin oblique parallelopiped bevilled unequally on all its four ſides. When the cryſtal is ſhort, the planes of its baſes approach to the rhomb, but when it is long, they become lengthened oblique parallelograms; in either caſe the plane angles are alternately 126° : 52′ : 12″ : and 53° : 7′ : 48″.

2. The long variety of the preceding, in which the parallelograms of the baſes are converted into hexagons, whence the reſult will be a lengthened hexahedral table with equal oppoſite angles and bevilled unequally on all the ſix ſides.

3. Another variety is produced by No. 1. being divided into two equal parts, by a plane paſſing parallel to the two longeſt ſides, and theſe halves being half turned round upon each other: in conſequence of this the planes at the baſes will be hexagons, with one re-entering angle oppoſite to an equal ſaliant one.

4. An octohedral priſm with alternate broad and narrow ſides, terminated by tetrahedral ſummits.

5. A ſtrait hexahedral priſm of which the baſes are ſlightly convex. When the priſm diſappears the cryſtal paſſes into the next variety.

6. A ſpherical convex lens. Theſe lenſes are either ſolitary or ſet edge-wiſe, forming the cock's-comb gypſum, or arranged circularly like the petals of a flower, or adhering together in pairs by part of the ſurface near the extremity of the diſk, thus forming a ſaliant angle oppoſite to a re-entering one; when ſeveral of theſe are accumulated on each other, diminiſhing gradually in ſize, and the ſaliant angle of the inferior pair fitting into the re-entering angle of the ſuperior pair, an aggregate is produced reſembling the head of an arrow; this variety is often found a foot or more in length.

The planes correſponding to the baſes of the original priſm are ſmooth, and more or leſs ſpecular, the others are longitudinally ſtriated and ſhining. The magnitude of the cryſtals varies from middle-ſized to large. Its internal luſtre is bright ſhining between vitreous and pearly.

The fracture of ſelenite is perfectly foliated either ſtrait or curved: it is diviſible in three directions, of which one parallel to the baſe of the original priſm is very well determined, and the two other lateral diviſions may be obtained by gently and judiciouſly ſtriking a thin lamina with any hard body; the ſurfaces thus diſcovered are however much leſs ſhining than the former. The fragments are rhomboidal, ſpecular on two ſurfaces, and ſtriated on the four others. When in maſs it ſometimes preſents coarſe granular or teſtaceous diſtinct concretions. It is commonly tranſparent, but ſometimes only tranſlucent, and has then often a diſagreeable odour when rubbed. It poſſeſſes a double refraction; is ſo ſoft as to be ſcratched by calcareous ſpar; is flexible in thin plates, but not elaſtic; is eaſily frangible, but not very brittle. Sp. gr. 2.26 to 2.32.

It is infuſible in the focus of the moſt powerful lens, nor does it yield to a blow-pipe ſupplied with oxygen gas, if it is not laid on a charcoal ſupport. When expoſed to the com-

[a] Emmerling, Hauy, Brochant, Jameſon, Kirwan.

mon blow-pipe it undergoes little alteration if the flame is directed to the ſurface of the laminæ, but if the interior *blue* flame is made to play on the *edges* of the laminæ, or the ſtriated ſurfaces, it ſoon melts into an opake white globule, probably in conſequence of its acid being partly converted into ſulphur. When dried as highly as poſſible without injuring its tranſparency it contains, according to Kirwan,

Lime - - -	34
Sulphuric acid	48
Water - -	18
	100

Selenite abounds at Mont Martre near Paris, at Shotover hill near Oxford, of ſingular beauty at the ſalt-mines in Upper Auſtria, alſo in Saxony, Spain, and elſewhere.

2 Subſpecies. Fibrous Gypsum. *Gypſe fibreuſe*, Broch. *Faſriger Gips*, Wern.

Its colour is ſnow-white, yellowiſh, greyiſh, or reddiſh-white, fleſh red and light hyacinth brown: ſeveral of theſe colours occaſionally coexiſt in the ſame ſpecimen, forming ſtripes and bands. It occurs acicular and in maſs, but never in very thick beds. Its internal luſtre varies from gliſtening to bright ſhining, with a pearly luſtre. Some varieties notwithſtanding their fibrous texture are almoſt ſpecular. Its fracture is parallel-fibrous either ſtrait or curved, and ſometimes almoſt paſſing into radiated; the fibres themſelves vary from thread-ſhaped to broad and flattened. In the department of Aveyron is a remarkable variety of gypſum, conſiſting of the broad foliated or ſelenite, penetrated at right angles to its principal fracture by fibrous gypſum, hence it is foliated in one direction and fibrous in another.

Its fragments are long-ſplintery. It is ſemitranſparent paſſing into ſemitranſlucent; when poliſhed it becomes irideſcent: its hardneſs is for the moſt part ſomewhat inferior to the preceding ſubſpecies: it is eaſily frangible and is brittle. Sp. gr. 2. 3. It never efferveſces with acids. It is affected by the blow-pipe, &c. in the ſame manner as the preceding.

3 Subſpecies. Granularly - foliated Gypsum or Alabaster. *Gypſe lamelleux.* Broch. *Korniger gips.* Emmerl. *Blættriger gips.* Wern.

Its colour is ſnow-white, greyiſh, yellowiſh, or reddiſh white; fleſh-red, blood-red, and brick-red; wax-yellow, ſmoak-grey and greyiſh black. Several of theſe colours are combined in veins, ſpots, and bands. It occurs maſſive and in blunt-edged fragments. It is tranſlucent; its luſtre is between pearly and vitreous, and varies from ſhining to gliſtening. Its fracture is foliated, generally ſomewhat curved, and paſſing into radiated; its fragments are indeterminately angular and blunt-edged. It abounds in fine and coarſe granular and priſmatic diſtinct concretions; when fine-grained it often crumbles between the fingers like tender ſandſtone. In hardneſs it exceeds the preceding variety, but is eaſily frangible. Sp. gr. 2.27 to 2.31.

It generally efferveſces more or leſs with acids on account of the carbonat of lime with which it is mixed. There is a conſiderable external reſemblance between this and granular limeſtone, from which however it is at once diſtinguiſhable by its inferior hardneſs. It paſſes by inſenſible degrees into the next ſubſpecies.

4 Subſpecies. Compact Gypsum or Alabaster. *Gypſe compacte.* Broch. *Dichter gips.* Wern. and Emmerl.

Its colour is aſh-grey, paſſing into ſmoak and yellowiſh-grey. It occurs in maſs. Internally it is dull with a few glimmering particles. Its fracture is even, paſſing into ſplintery and very fine granular. Its fragments are indeterminately angular, blunt-edged. It is tranſlucent on the edges, is ſoft and eaſily frangible, but not very brittle, has a dry but not a harſh feel. Sp. gr. 2.3. Like the preceding it commonly efferveſces with acids.

5 Subſpecies. Earthy Gypsum. *Gypſe terreux.* Broch. *Gipſerde.* Wern.

Its colour is yellowiſh-grey paſſing into yellowiſh-white, or ſnow-white. It is compoſed of pulverulent grains ſlightly adhering together: it is for the moſt part dull, but contains a few glimmering particles; has a harſh meagre feel, but is not gritty between the teeth; it ſtains the fingers, and is eaſily broken down into powder. When heated a little below redneſs it becomes of a dazzling white: it uſually gives a ſlight efferveſcence with acids. It is of rare occurrence, and appears always to originate from depoſitions made from water that has flowed over a bed of gypſum.

II. Family. Affords little or no water by diſtillation; does not become opake and fall into powder at a temperature below a red heat.

6 Subſpecies. Anhydrous Selenite. *Chaux ſulfatée anhydre.* Hauy.

Its colour is greyiſh-white; it occurs in detached lamellæ or in ſlightly cohering foliated maſſes. It is diviſible with equal eaſe and neatneſs in all directions, hence its primitive molecule is a cube. It is tranſlucent, and poſſeſſes a conſiderable luſtre. Its hardneſs is ſomewhat ſuperior to that of calcareous ſpar; ſp. gr. 2.96.

It requires a much larger quantity of water

for its solution than common selenite. Its component parts according to Vauquelin, are

Lime - - - -	40
Sulphuric acid -	60
	100

It has hitherto been found only in the salt mines of the canton of Berne in Switzerland.

7 Subspecies. MURIACITE (of Poda.) *Soude muriatée gypsifère.* Hauy.

The colour of this is greyish white, greyish black, or reddish white. It occurs in loosely adhering rectangular plates, with bright specular surfaces; its primitive molecule is a cube. Its hardness is superior to that of common gypsum. It is weakly saline to the taste, it requires 4300 parts of water for its solution. It has been analyzed by Klaproth,[b] and appears to consist essentially of

Gypsum - - -	65
Muriated soda -	35
	100

It is found in the salt-pit of Halle in the Tyrol, and is called by the miners scaly gypsum (schuppiger gypsstein). It was first introduced to the notice of mineralogists by the Abbé Poda, who erroneously supposed it to consist of muriat of lime.

8 Subspecies. GRANULAR ANHYDROUS GYPSUM. *Chaux Sulfatée Quartzifere.* Hauy. *Pierre de Vulpino. Bardiglio marble* of the Statuaries.

Its colour is greyish white, veined with greyish blue; its fracture is fine-granular passing into splintery; its lustre is glimmering; its hardness is inferior to that of statuary marble, but it cannot be scratched by the nail. Sp. gr. 2.87.

It is moderately phosphorescent by heat, is very fusible before the blow-pipe, and effervesces strongly with acids. It consists according to Vauquelin, of

Sulphated lime - -	92
Silex - - - - - -	8
	100

It is found near Vulpino in the Bergamese, and is employed by statuaries for chimney-pieces, &c.

Concerning the three latter subspecies, which are supposed by Hauy to belong to the class of anhydrous gypsum, it will be necessary to say a few words. Of these the first (No. 6) is the only one that has been analyzed with sufficient accuracy. It appears to have been taken in hand by Vauquelin himself, and therefore there is no reasonable ground for suspecting the exactness of the given analysis; we may therefore conclude it to be ascertained that there exists such a combination as sulphuric acid and lime, destitute of water of crystallization; and that this combination essentially differs from common gypsum in the cubical form of its molecules, in its superior hardness and greater specific gravity.

The gypsum in muriacite is supposed by Hauy to be anhydrous merely from its cubical molecule, and the large proportion of water required for its solution; yet we may infer that it contains water from the result of the Abbé Poda's analysis, however incorrect in other respects; he would hardly have stated it to contain lime, muriatic acid, and *water*, except he had actually procured some of this fluid from it by distillation. The Bardiglio marble is supposed to belong to the same family, first, because it is stated on the authority of Vauquelin to contain 92 per cent. of gypsum, and therefore from its specific gravity amounting to 2.87 it is inferred that this must be the anhydrous gypsum whose sp. gr. is 2.96, rather than the common, whose sp. gr. does not exceed 2.32. We are very much inclined however to disbelieve the reported analysis, not from any suspicion of the accuracy of Vauquelin himself, but because we are persuaded that many analyses made in his laboratory and by his pupils, are allowed very unjustly to pass current in the world under the name and authority of Vauquelin. This Bardiglio marble effervesces very vehemently with nitrous acid, and we are almost inclined to suspect that in the analysis *sulphat* of lime has been inadvertently mentioned instead of *carbonat* of lime. If this is the case the great specific gravity is also accounted for, that of common granular limestone being = 2.83, and the impure varieties of the same being still heavier.

There appear to be three very distinct formations of gypsum. The oldest belongs to the class of primitive mountains, and has hitherto been only met with in the vicinity of Bellinzone, among the Italian Alps. It forms alternate beds with gneiss, has a schistose texture, and abounds in mica. Gypsum of the second formation rests upon the oldest floetz limestone, and is disposed in beds alternating with swine-stone, and occasionally with rock salt. The gypsum of this formation is mostly the compact

[b] Analyt. Ess. I. p. 263.

and granularly foliated, it contains ſeveral ſubſtances imbedded in it, ſuch as quartz, arragonite, boracite and ſulphur, and moſt of the ſalt ſprings are found in this formation. The moſt recent gypſum reſts upon the ſecond ſandſtone formation, and alternates with indurated clay and ſandſtone, and is frequently covered with ſecondary floetz limeſtone; fibrous gypſum is chiefly characteriſtic of this formation, and it contains as well as the preceding the bones of quadrupeds, but ſcarcely any other organic remains.

Gypſum generally forms banks and hills of little elevation in plain countries, or at the mouth of large vallies. It abounds in the neighbourhood of Paris, at the foot of the Alps in Switzerland, Italy, and Tyrol; in Bavaria, Saxony, Thuringia, Poland and Spain; in England, in Derbyſhire, Yorkſhire, and Nottinghamſhire; in Pennſylvania in North America.

The uſes of gypſum are very extenſive; when it is ſufficiently compact it is employed by the architect for columns and other ornaments, being eaſier to work than marble; it is alſo turned by the lathe into cups, baſons, vaſes, and other ſimilar articles. When expoſed to a low red heat it parts with its water of cryſtallization, is converted to a fine powder called plaſter of Paris, like meal, and this when beaten up with water to the conſiſtence of paſte, ſhortly after ſets and becomes ſolid, hence it is largely uſed for taking caſts of various magnitude, from a medal to a coloſſal ſtatue, and enters into the compoſition of many cements. For further particulars relative to the chemical properties of this ſubſtance, ſee SULPHAT OF LIME.

H

HÆMATITE. See IRON, *Ores of.*

HAIR. The chemical compoſition of hair appears by the experiments of Mr. Hatchett to reſemble very cloſely that of nail and horn. Boiling water extracts from hair a very ſmall portion of gelatin, and the hair after drying is ſomewhat ſtiffer and more brittle than before. The chief conſtituent of hair appears to be organic, condenſed albumen. (See HORN.)

Hair may be dyed permanently in ſeveral ways. A black or dark colour, which is generally deſired, is given by many metallic ſolutions, particularly that of ſilver much weakened, but theſe are liable to corrode its ſubſtance, if not carefully uſed. Pallas[a] relates that the women of Aſtracan dye their hair, while growing, of a fine gloſſy black, in the following way: twenty-five galls are firſt boiled in oil, then dried and powdered: to this is added, 3 drams of green vitriol, one dram of cream of tartar, and one dram of indigo, and the whole ſtirred up with a quart of water, to which is added a handful of the dyeing herb *henne*. The hair is anointed with this over night, care being taken not to blacken the ſkin, and is waſhed in the morning. This application gives a ſhining black which laſts ſeveral months.

HALBOPAL. See OPAL.

HARMATOME. See STAUROLITE.

HARTSHORN, *Salt, Spirit, Oil, & Earth of.*

Salt of Hartſhorn is properly the carbonat of ammonia, prepared by the ſimple diſtillation of bone, or ſtag's horn, purified by rectification. It is a tolerably pure carbonat of ammonia, but retaining a ſtrong ſub-empyreumatic ſcent of the animal oil, which is intimately mixed with it, and is apt to render it yellow. The ſpirit of hartſhorn is this ammoniacal ſalt diſſolved in alcohol, by the medium of diſtillation, and is a ſtrong and powerful cordial and ſtimulant.

The *Oil of Hartſhorn* is commonly dark-coloured and fetid, but may be rendered limpid and fragrant by rectification. It is then called *Dippel's Oil.* The *Earth of Hartſhorn* is phoſphat of lime. *(See the articles* HORN and BONE.*)*

HEAT. See CALORIC.

HEAVY-SPAR. *Baroſelenite* Kirw. *Schwerſpath,* Wern. *Spath peſant,* Broch. *Baryte Sulfatée,* Hauy.

Of this mineral there are the following ſubſpecies.

1. Subſpecies. FOLIATED HEAVY-SPAR. *Gerad-ſchaaliger and Krummſchaaliger Schwerſpath,* Wern.

The principal colours of this ſubſtance are milk-white, greyiſh yellowiſh and reddiſh-white, yellowiſh-grey, ſmoak and pearl-grey, wine yellow, yellowiſh-brown, fleſh-red, blood and liver-red, alſo very rarely greyiſh-black; greeniſh-grey, olive and oil-green; bluiſh-grey, ſmalt and indigo-blue.

It occurs cryſtallized, in maſs, reniform, and globular.

Its primitive figure is a ſtrait rhomboidal priſm, the meaſure of whoſe angles is 101° 30′ and 78° 30′: and this is again diviſible by planes

[a] Travels in the Taurida.

paſſing through the diagonals of the baſes, into four ſtrait triangular priſms, with rectangular baſes. The other varieties of cryſtallization that it preſents are,

1. The octohedron, uſually wedge-pointed, but ſometimes regular.

2. The primitive figure with the obtuſe ſolid angles, replaced by triangular planes.

3. A ſix ſided table, ſometimes elongated.

4. A four ſided table, bevilled at the edges.

5. The ſame with the ſolid angles replaced by quadrilateral facets.

6. A compreſſed ten-ſided priſm, with dihedral ſummits.

7. The ſame as No. 5. with the lateral edges replaced by narrow quadrilateral planes.

8. An octohedral priſm more or leſs compreſſed, and terminated by ſummits compoſed of ſeven or more faces.

9. Lenticular, either ſingle or aggregated.

The planes of the cryſtals are ſmooth, and generally bright ſhining, with a pearly luſtre. Internally it varies from bright ſhining to gliſtening, with a luſtre between pearly and vitreous. Its fracture is either ſtrait, or curved foliated, paſſing occaſionally into ſplintery and radiated; the ſtrait foliated preſents ſtrait, lamellar, wedge-ſhaped, diſtinct concretions, the curved foliated preſents curved and thick lamellar diſtinct concretions. The cryſtallized varieties poſſeſs a double refraction, and are tranſparent, and ſemitranſparent: the others are moſtly tranſlucent. Its hardneſs is between that of calcareous and fluor ſpars. It is eaſily frangible, but not particularly brittle. Sp. gr. 4. 3 to 4. 47.

When pure it does not effervеſce with acids. It melts without addition before the blowpipe into a white enamel. Its component parts according to Withering, are

Barytes - -	67. 2
Sulphuric acid	32. 8
	100. 0

The maſſive and globular varieties generally however contain a little ſulphat of ſtrontian, together with ſilex and iron.

It occurs uſually in veins, ſeldom in beds, in rocks of almoſt every formation, from primitive to the neweſt floetz-trap: next to quartz and calcareous ſpar, it is the moſt abundant material of mineral veins, and particularly of thoſe which contain galena and grey antimony.

2. Subſpecies. COLUMNAR HEAVY SPAR. *Stangen-ſpath.* Wern.

Its colour is milk-white, yellowiſh, greyiſh, and greenith-white. It occurs always cryſtallized in needle-ſhaped rhomboidal priſms, which are columnarly aggregated, and interſect one another. It has a brilliant, pearly, and in ſome inſtances, almoſt ſemimetallic luſtre: its longitudinal fracture is ſtrait foliated: its fragments are rhomboidal: it is ſoft, eaſily frangible: ſp. gr. 4. 5.

It is found in metallic veins, in Saxony and Derbyſhire, and is often miſtaken for white lead ore; from which however it differs, in poſſeſſing leſs luſtre, and inferior ſpecific gravity.

3. Subſpecies. BOLOGNIAN SPAR. *Bologneſer ſpath.* Wern.

Its colour is ſmoak-grey, paſſing into aſh and yellowiſh-grey. It occurs imperfectly lenticular, and in compreſſed pieces. Its luſtre internally varies from ſhining to gliſtening and reſinous. Its fracture is radiated, paſſing into obſcurely foliated. Its fragments are wedge-ſhaped, or indeterminately angular. It ſometimes occurs in large-grained diſtinct concretions. It is ſtrongly tranſlucent. When rubbed, it gives out a fetid ſulphureous odour. In other characters it agrees with ſubſpecies 1.

It is found imbedded in clay and marl at Monte Paterno, near Bologna in Italy. For its phoſphoreſcent quality, ſee PHOSPHORI *ſolar.*

4. Subſpecies. GRANULAR HEAVY SPAR. *Körniger Schwerſpath.* Wern.

Its colour is ſnow-white, milk-white, and ſmoak-grey. It occurs always in maſs. Its luſtre is gliſtening and pearly. Its fracture is ſmall and fine foliated, paſſing into ſplintery. Its fragments are indeterminately angular and blunt-edged. It preſents ſmall, fine-grained diſtinct concretions. It is feebly tranſlucent, is moderately hard, and eaſily frangible. Sp. gr. 4. 38.

It undergoes no loſs of weight by ignition: its component parts according to an analyſis by Klaproth, are,

Barytes - -	60	90 Sulphat of barytes
Sulphuric acid	30	
Silex - - - - -	10	
	100	

It occurs in beds with galena, at Peggau in Stiria, in the vicinity of Freyberg, and at Schlangenberg in Siberia with malachite and native copper.

In its external appearance it ſingularly reſembles the pureſt granular limeſtones, but may be diſtinguiſhed independently of chemical cha-

racters, by its inferior luſtre, and ſuperior ſpecific gravity.

5. Subſpecies. COMPACT HEAVY SPAR. *Cawk* of the Derbyſhire miners. *Dichter Schwerſpath*, Wern.

Its colour is yellowiſh-white, paſſing into greyiſh-white. It occurs in maſs, and in kidney ſhaped and hemiſpherical nodules. It is either dull or has a glimmering luſtre. When dull, its fracture is coarſe earthy; when glimmering, its fracture is ſmall radiated, paſſing into granularly foliated. Its fragments are indeterminately angular, and blunt-edged. It often preſents thick, curved, lamellar, diſtinct concretions. It is opake; ſometimes tranſlucent on the edges; has a meagre feel, is ſoft, and eaſily frangible. It is found in metalliferous veins in Saxony, Savoy, Derbyſhire, &c.

6. Subſpecies. EARTHY HEAVY SPAR.—*Schwerſpath erde*, Wern.

Its colour is reddiſh or yellowiſh-white. It occurs in maſs, and conſiſts of glimmering, and generally coarſe earthy particles. It does not ſtain the fingers: it is either pulverulent or friable; has a meagre and ſomewhat coarſe, rough feel. It occupies cavities in veins of heavy ſpar, and appears to be the dull variety of the preceding ſubſpecies, in a ſomewhat leſs indurated ſtate. It is found near Freyberg in Saxony, and in the mining diſtricts of Staffordſhire and Derbyſhire in England.

HELIOTROPE. *Heliotrop*, Wern.

Its principal colour is deep leek or celandine green, paſſing into mountain-green, and occaſionally into dark olive: it is alſo dotted with opake ſpots of a blood or ſcarlet red, or ochre yellow. It occurs maſſive; in angular or rolled pieces. Its internal luſtre is gliſtening, nearly reſinous: its fracture is large and imperfectly conchoidal, paſſing into ſcaly: its fragments are indeterminately angular, and ſharp-edged. It is commonly tranſlucent on the edges, ſometimes tranſlucent.

It is hard, and eaſily frangible. Sp. gr. 2.62 to 2. 7.

It is infuſible before the blowpipe without addition.

It is found in rocks belonging to the floetz-trap formation, and appears to be the connecting link between chalcedony and jaſper; according to Werner, it is an intimate mixture of chalcedony and green earth. It is found in Bucharia, Perſia and Siberia in Aſia; in Iceland, and Upper Saxony in Europe. From the beauty of its colour, and its hardneſs, it is in conſiderable requeſt among lapidaries. That which is the moſt tranſlucent, and has the greateſt number of red ſpots, is moſt eſteemed: it is known in commerce by the name of oriental or blood-jaſper.

HEPAR } See SULPHURET.
HEPATULE }

HEPATIC AIR. See SULPHURETTED HYDROGEN.

HOLZOPAL. See OPAL.

HOLZSTEIN. See WOOD petrefied.

HOMBERG's PHOSPHORUS is the common PHOSPHORUS, (which ſee.)

HONEY. *Miel*, Fr. *Der Honig*, Germ.

Honey, the moſt antiently uſed and one of the moſt grateful of all the ſaccharine juices, is a natural compound of a conſiderable portion of ſugar intimately mixed with ſeveral other ſubſtances that give it its ſlimy conſiſtence, its peculiar colour, ſmell, and flavour, together with a ſmall portion of natural acid.

Honey is found differing much in conſiſtence and colour, being ſometimes nearly as ſtiff as ſoft ſuet, ſometimes as thin as a balſam, and of various ſhades of yellow, gold-colour, brown, and ſometimes nearly white. The goodneſs of honey for culinary purpoſes is chiefly determined by the delicacy of flavour, but the comparative quantities of ſugar and other chemical differences have not been much examined.

When honey is gently warmed over a ſlow fire it liquefies and a thick ſcum riſes to the top, which when removed leaves the honey ſomewhat purer than before, and makes the *depurated* or *clarified honey* uſed in pharmacy. If the honey is naturally thick it ſhould be previouſly diluted with a little water. When clarified honey is ſlowly evaporated it becomes a thick tenacious maſs, loſes its delicacy of flavour, and acquires one ſomewhat diſagreeable, becomes brown and foul, and can never by this means be made to yield cryſtals of pure ſugar. The ſtronger the heat, and the browner and higher-flavoured it becomes. Whilſt evaporating, a vapour riſes, which takes fire at the approach of a candle and fills the houſe with a very ſtrong and penetrating ſmell. Neuman obtained from 32 ounces of honey by diſtillation *per ſe* on a ſlow fire about 24 ounces of an acid watery liquor mixed with a brown oil. The reſidue ſtrongly heated gave a coal difficult of incineration.

Owing to the abundant quantity both of ſugar and of extract or mucilage in honey, it very readily enters into the vinous fermentation and yields a very ſtrong wine, called *mead*, which poſſeſſes much of a honey flavour that leſſens by

keeping, and a very ſtrong body. Neuman obtained a mead from 36 ounces of honey diluted with 4 quarts of warm water and fermented with yeaſt, which by diſtillation and rectification gave 8 ounces of ſtrong alcohol.

The moſt intereſting experiments on honey are thoſe which have been made with a view of purifying it, and ſeparating the truly ſaccharine part from every other. For the purification from its peculiar flavour which is offenſive to ſome palates, and from the yellow colour, mere deſpumation and the other uſual modes of clarification will not anſwer; Mr. Lowitz has indeed found that when diluted with water and paſſed through freſh burnt charcoal [a] it loſt its ſmell and colour, but on again inſpiſſating it by a very gentle fire, it ſoon acquired its former brown colour and did not ſhew any tendency to cryſtallization. By long keeping, this honey ſpontaneouſly ſeparated into a maſs of white concrete granulated matter entangled in a viſcid ſlime. In this ſtate it reſembled the white concrete natural honey often met with. This concrete matter was diſſolved by hot alcohol, which left the other part nearly untouched. On letting the alcoholic ſolution ſtand at reſt for ſome days a number of ſpherical knobs began ſlowly to ſeparate, which gradually increaſed, forming a ſnow-white cruſt, which on being removed and dried would bear cutting with a knife into thin ſlices. This appeared to be the ſaccharine part of the honey in a conſiderable ſtate of purity, but ſtill ſo intimately united with ſome other ingredient as not to be cryſtallizable, as pure ſugar is, but only to ſeparate in theſe cauliflower-like knobs, which examined by the microſcope, appeared compoſed of ſmall thin longiſh cryſtals.

Mr. Lowitz alſo gives as characteriſtic differences between this white ſugar of honey and common white ſugar, that the former is rendered brown by lime-water, and with lime in ſubſtance and a little water a ſtrong effervеſcence takes place, and the mixture becomes black, thick, and nauſeous, which, clarified by charcoal and evaporated nearly to dryneſs, leaves a bitter yellow extract. None of theſe appearances take place with lime and common white ſugar, neither diſcolouration nor decompoſition being produced. The cauſtic fixed alkalies alſo produce a ſimilar effect upon the ſugar of honey, but not upon common ſugar. *(See the article Sugar.)* The ſaccharine part of honey therefore appears moſt intimately combined with the extractive, and it appears probable that no direct attempts to procure pure ſugar from honey will ſucceed, except by going through the whole proceſs by which ſugar is obtained from the cane juice. In this latter way, and with the uſe of claying, Neuman aſſerts that he has obtained a good ſugar from honey reſembling the fine moiſt ſugars prepared in this way, but ſtill not in the form of hard well-defined cryſtals.

Honey is often adulterated with flour, which may be detected by diffuſing it in blood-warm water, by which all the honey will be diſſolved and the flour remain nearly unaltered, and a ſubſequent boiling of the reſidue in the water will convert the flour into thick paſte.

Honey is uſed only for culinary and medicinal purpoſes. The diſtilled acid ſpirit was formerly thought, but quite erroneouſly, to be a ſolvent for gold and ſilver. The ſame *honey-water* has the reputation of making the hair grow, and with as little foundation.

HONEYSTONE. } See MELLITE.
HONIGSTEIN. }

HORN.

Under the general article of horn may be included (chemically conſidered) a great variety of tough, ſomewhat flexible, ſemitranſparent organs intended by nature for defence or covering. Of this kind are the hollow horns of the ox, goat, ram, and ſome other animals, the hoof, the horny claw and nail, and the horny ſcale of certain inſects and animals, chiefly cold-blooded, ſuch as the *ſhell* (ſo called) of the tortoiſe. All theſe reſemble each other very cloſely in chemical character, and differ conſiderably from ſome of the harder and bony defences of ſome animals, ſuch as the ſtag's-horn, ivory, and the hard tuſks of the ſea-cow, and many others.

Horn (uſed in the above general ſenſe) has various degrees of hardneſs, but is always in ſome degree tough and flexible, even in the cold, ſo that however dried, it cannot be bruiſed to powder as bone can. It is alſo diſtinguiſhed from bone very remarkably, in being ſoftened very compleatly by heat, either naked, or through the medium of water, ſo as then to be readily bent, moulded, and made to adhere by preſſure to other pieces of horn in the ſame ſtate.

No ſuch change takes place with bone.

The valuable experiments of Mr. Hatchett[a], with thoſe of preceeding chemiſts, have alſo ſhewn a moſt decided chemical difference between horn and bone. When bone is boiled with water in an open veſſel, (as mentioned under that article) a large quantity of *gelatin* is extracted, and the inſoluble reſidue conſiſts

[a] Phil. Tranſ. vol. 90. p. 372.

of the earth of bone, together with the albuminous cartilage, ſo that the texture remains unbroken. On the other hand, the different ſpecies of horn boiled with water even for many days, give to it but very little gelatin, or any other principle, but of this ſmall portion of gelatin, the ſofter and more flexible horns give the moſt. The horn itſelf during the digeſtion, is ſoftened conſiderably by the hot water, but on being taken out and dried, it becomes more brittle than at firſt, and in proportion to the loſs of gelatin. Bone therefore contains much gelatin, and horn ſcarcely any.

Another difference appears after the utmoſt action of fire on each. When bone is burnt, a number of ſubſtances are procured, as deſcribed under that article, and the laſt reſidue is an earthy ſalt, chiefly phoſphat of lime, amounting on an average to from half to one third of the entire weight of the bone. When horn is treated in the ſame way, the volatile products are indeed the ſame, or nearly ſo, but inſtead of a large earthy reſidue, ſcarcely any earth, or any other combuſtible matter remains. Bone therefore contains much phoſphat of lime, but horn hardly any.

But the ſubſtance which they poſſeſs in common is that condenſed tough matter, inſoluble in water and weak acids, which Mr. Hatchett has ſo ſatisfactorily ſhewn to reſemble albumen in all eſſential properties, and which in bone forms the original organic cartilage on which the earth is depoſited during the growth of the animal, and in horn forms almoſt the whole ſubſtance.

The peculiar properties that identify this ſubſtance with the albumen of eggs, have been already fully deſcribed under the articles *Bone*, *Albumen*, and *Gelatin*, and need not be here repeated.

Horn therefore ſeems to conſiſt in by far the largeſt proportion of condenſed albumen, combined however with a ſmall and varying portion of gelatin, which modifies its texture and flexibility, and alſo with a ſmall portion of phoſphat of lime.

It has been mentioned that boiling water in *open* veſſels had hardly any action on horn, but when *confined in a digeſter*, horn as well as bone is totally ſoluble, becauſe water aſſiſted by the ſtrong heat of a digeſter, will diſſolve condenſed albumen as well as gelatin. This method therefore is not ſufficiently diſtinctive for chemical analyſis.

The fixed alkalies readily and totally diſſolve horn into a yellow ſaponaceous liquor.

The products obtainable from horn and bone of all kinds by diſtillation per ſe, were early attended to by chemiſts, as it is from theſe ſubſtances that a variety of valuable ammoniacal ſalts and preparations are obtained.

The products from bone and horn by fire are very ſimilar, as it is only the ſoft parts, ſuch as gelatin and albumen, that are decompoſed in the proceſs, the earthy phoſphat remaining inert without adding to or modifying the volatile products. Theſe latter are a weak ammoniacal phlegm or water, on the firſt impreſſion of the fire, to which ſucceeds an oil thin and limpid at firſt, but afterwards brown and foul, and at laſt of a pitchy colour and conſiſtence, and an extremely fetid empyreumatic ſmell. During the whole of the diſtillation, carbonat of ammonia comes over, partly diſſolved in all the liquid products, and partly concreting on the ſides of the receiver in cryſtalline plates. A ſecond diſtillation with regulated heat is uſed to procure the ammonia purer; but it can hardly ever be totally freed by this means from the volatile oil; ſo that, though limpid and gratefully ammoniacal, the alkaline liquor or ſalt thus obtained, always retains ſomewhat of the peculiar ſmell of the oil, as muſt be obſerved by every one who compares the ſcent of common *ſpirit of hartſhorn* with that of the pure carbonat of ammonia or *ſal volatile*, which is prepared in a different way, and from other materials.

But horn (properly ſpeaking) is ſeldom employed for the purpoſe of diſtillation, being too valuable as an article of manufacture to be thus ſacrificed. The only horn ever uſed thus is the *ſtag's* or *hartſhorn*, which as above mentioned, partakes much more of the nature of bone, is not flexible like ox and other horn; when in ſhavings, readily diſſolves by boiling water into a pure nutritious gelly, entangling the phoſphat of lime along with it, which makes it ſlightly opake. Stag's horn therefore is ſomewhat intermediate in properties between bone and true horn.

Horn and tortoiſe ſhell being applied to a number of mechanical purpoſes, muſt be cut, bent and ſhaped in an infinite variety of ways. This is done in moſt inſtances by the aſſiſtance of heat applied either dry, with warmed irons or burning charcoal, or by ſoftening the horn in boiling water, and ſometimes with the aſſiſtance of a weak alkaline liquor. When thus ſoftened, one part may be made to adhere to another by mere preſſure as firmly as the undivided ſubſtance. Thus for example, to make the horn

ring that furrounds a common opera glafs, a flat piece of horn is cut out of the requifite fhape, the ends intended to join are thinned down by a file, the piece is then put into boiling water till fufficiently fupple, and is then rolled round a warmed iron cylinder, and held in that pofition by a vice, fo that the ends overlap each other. Another piece of iron heated and grooved is then laid upon the feam of the joined ends, and preffed upon the cylinder, and confined there by iron wire; and the heat of the two partially melts that portion of the horn, and cements the ends fo compleatly, that no feam or joining can be obferved when cold.

In a fimilar manner, two pieces of tortoife-fhell may be joined together, by firft neatly fhaping with a file the parts that are to be united, then tying a thick paper doubled in feveral folds over the joining, and preffing the whole together with a hot iron inftrument like curling irons, heated juft fufficiently that the fhell when warmed by it, will begin to bend by its own weight. When cold, the joining is perfect, and without feam. Too great heat would make the fhell rife in white opake blifters, and fpoil its beauty.

Horn is made to imitate tortoife-fhell, in the following manner:[a] make a paſte with two parts of quick-lime, one of litharge, and a little foap-makers' ley, or folution of cauftic pot-afh; apply it fkilfully on a thin plate of horn in a way that will beft imitate the natural fpots of the tortoife-fhell, leaving the light parts untouched; let this paſte dry on, then brufh it off, and the horn will be permanently ftained. The effect is much improved by laying beneath it when ufed, a piece of brafs leaf. This ftaining may be varied at pleafure, by fubftituting other coloured fubftances to the litharge.

HORNBLENDE. *Amphibole*, Hauy.

Of this mineral there are the following fubfpecies.

I. Basaltic Hornblende. *Baſaltiſche Hornblende*, Wern.

Its colour is pure black, greyifh or greenifh-black: by decompofition it becomes browniſh-black and acquires a fuperficial varying tint of colour. It occurs almoft always in fingle imbedded cryftals. Its primitive form is an oblique prifm with rhomboidal bafes, the angles of which are refpectively 122°: 56' and 57°: 4'. The other varieties of cryftallization that it offers are,

1. A fix-fided prifm with trihedral rhomboidal fummits.

2. The fame prifm terminated at one extremity by a tetrahedral and at the other by a dihedral fummit.

3. The fame as No. 1, except that one of the fummits is dihedral.

4. The fame as No. 2, except that four fmall rhomboidal facets are added to the dihedral fummit.

5. A fix-fided prifm terminated at each extremity by fix facets, but diffimilar.

The cryftals are fmall and middle-fized. The furface is fmooth and fhining except where it happens to be covered by a thin ochery cruft. Its longitudinal fracture is perfectly ftrait foliated; the crofs fracture is uneven and fmall conchoidal: the luftre of the principal fracture is bright-fhining, that of the other is glimmering and vitreous. The fragments are indeterminately angular approaching to rhomboidal. It is opake, gives a greyifh white ftreak, is moderately hard and eafily frangible; it exhales an argillaceous odour when breathed upon. Sp. gr. 3.15 to 3.3.

Before the blowpipe it melts, with more difficulty than common hornblende, into a browniſh-black glafs. Its component parts, according to Bergman, are

Silex - - -	58
Alumine - -	27
Iron - - -	9
Lime - - -	4
Magnefia - -	1
	99

It is found imbedded in baſalt and wakke and in lava: being for the moft part lefs decompofable than baſalt, many fine cryftals are procured from the clay which is found at the foot of moft baſaltic rocks. The cryftals met with in lava not unfrequently affect the magnet. It is found in Saxony, Bohemia, Italy, Scotland, &c.

II. Common Hornblende. *Gemeiner Hornblende*, Wern.

Its colour is greenifh or reddifh black, greyifh black or greenifh-grey. It occurs in mafs, difſeminated and cryftallized: the cryftals are imbedded and interfect one another, fo that they cannot be very accurately determined, but they ſeem to be ſlight modifications of the primitive figure as deſcribed under the preceding fubſpecies. Internally it is more or lefs brightly fhining, with a pearly luftre. The fracture is ſtrait rarely curved-foliated, paſſing into broad-

[a] Encyclop. Arts de Metiers, Art. Ecaille.

radiated: the fractured ſurface is generally longitudinally ſtriated. The fragments are indeterminately angular blunt-edged, paſſing into rhomboidal. It preſents granular diſtinct concretions. The lighter coloured varieties are uſually tranſparent on the edges. It gives a greeniſh grey ſtreak, is moderately hard, tough and difficultly frangible. When moiſtened it gives out a ſtrong argillaceous odour. Sp. gr. 3.6 to 3.8.

It melts eaſily before the blowpipe into a greyiſh black glaſs. The following are the reſults of its analyſis.

	Kirw.	Wiegleb.	Hermann.
Silex - -	37	— 48.83	— 37.
Alumine -	22	— 0	— 27.
Magneſia -	16.	— 17.5	— 3.
Lime - -	2.	— 16.66	— 5.
Oxyd of iron	23.	— 17.5	— 25.
	100.	100.49	97.

Hornblende forms an eſſential conſtituent part of ſyenite and primitive greenſtone, alſo of tranſition and floetz-greenſtone, and enters accidentally into granite, gneiſs, micaceous ſchiſtus and granular limeſtone. It forms alſo entire beds which generally incloſe magnetic iron. When in maſs it forms an excellent flux for iron ores, and is largely employed in Sweden for this purpoſe.

III. Labrador Hornblende. *Labradoriſche Hornblende*, Wern.

Its colour is browniſh-black, greeniſh-black, copper-red, tombac-brown and greyiſh-black. It occurs in maſs, diſſeminated and in rolled pieces. It varies from glimmering to ſhining, and has a ſemi-metallic luſtre. Its fracture is uſually curved foliated; its fragments indeterminately angular tending to rhomboidal. It preſents lamellar diſtinct concretions; is opake, moderately hard, and not difficultly frangible. Sp. gr. 3.38.

It is found in the Iſle of St. Paul on the coaſt of Labrador.

IV. Hornblende Slate. *Hornblendeſchiefer*, Wern.

Its colour is between greeniſh and reddiſh-black. It occurs in maſs forming entire beds. Its luſtre approaches to pearly and varies between ſhining and gliſtening. Its fracture in the great is ſlaty, in the ſmall is confuſedly radiated. The fragments are generally tabular. It gives a greeniſh-grey ſtreak, is opake, moderately hard, not very frangible. It is often mixed with quartz, in which caſe its hardneſs is increaſed, alſo with felſpar and mica.

It forms thick beds in primitive and tranſition rocks, eſpecially in argillite, gneiſs, and micaceous ſchiſtus.

HORNERZ. See Silver, Ores of.

HORNSTONE. Of this mineral there are two ſubſpecies.

I. Splintery Hornstone or Chert. *Splittriger Hornſtein*, Wern.

Its colour is uſually grey, ſuch as bluiſh, greeniſh, yelloviſh, ſmoak and pearl-grey, blackiſh-grey and greyiſh-black; it is alſo found fleſh red, blood and liver red, olive green and mountain green. It occurs in maſs and globular, and occaſionally impreſſed by pyramids of calcareous ſpar. Its fracture is ſplintery, often fine ſplintery and with a tendency to conchoidal. It poſſeſſes no luſtre when pure, but when mixed with quartz it becomes glimmering: its fragments are indeterminately angular, more or leſs ſharp edged. When in maſs its texture is uniform, the globular variety preſents concentric lamellar diſtinct concretions. It is more or leſs tranſlucent. It is hard, tough, moderately heavy and difficultly frangible. Before the blowpipe it becomes opake, but is infuſible *per ſe*.

II. Conchoidal Hornstone. *Muſchliger Hornſtein*, Wern.

This differs from the preceding in the following particulars. It occurs only in maſs, its colours are for the moſt part lighter, it is tranſlucent only at the edges; its fracture is perfectly conchoidal; it is not ſo tough and therefore more eaſily frangible than the ſplintery variety.

There appear to be at leaſt two diſtinct formations of hornſtone, independent of hornſtone Porphyry, which is ranked among the primitive mountains; of theſe the eldeſt occurs in tranſition mountains of argillite and greenſtone, and appears to paſs into quartz on one ſide and into hone ſlate (wetzſchiefer) on the other; it forms veins and ſometimes beds, and is mixed not unfrequently with iron or copper pyrites. The more recent hornſtone occurs in ſecondary floetz limeſtone, with the ſtrata of which it alternates as flint does with chalk. This hornſtone it is which is known to Engliſh miners by the name of chert; its colour is greyiſh-white or greyiſh-black; by calcination it becomes milk white; it paſſes not into quartz but into chalcedony.

All thoſe kinds of hornſtone that become white by calcination form an excellent material for the better kinds of pottery. The beſt millſtone called French bur is cellular ſplintery hornſtone.

HYACINTH. See Zircon.

HYACINTH OF VESUVIUS. See VESUVIAN.

HYALITE. See THUMERSTEIN.

HYDRAT. This term has been applied by ſome late chemiſts, particularly by Prouſt, to expreſs the chemical union of water with any ſubſtance and eſpecially with ſome metallic oxyds. Thus the *hydrat of copper* is a blue-green oxyd of this metal, which differs from the brown oxyd only (as appears) in containing a large quantity of water, which a low red heat will expel.

HYDROGEN GAS, or *Inflammable Air. Waſſerſtoff Gas*, Germ.

Scarcely any ſubſtance has ſo much engaged the attention of modern chemiſts, and is ſo intimately concerned in the controverſy between the ſupporters of the phlogiſtic and antiphlogiſtic theory of chemiſtry, as inflammable air in its various modifications. The preciſe date of the diſcovery of this gas is not certainly known, but it is unqueſtionably owing chiefly to the valuable reſearches of Mr. Cavendiſh that the production of water and the combuſtion of inflammable air have been proved to be conſtantly concomitant, and the numerous experiments of Dr. Prieſtley have had an equal ſhare in firſt explaining its nature and properties.

Till the exact nature of this gas was explained by late reſearches, much confuſion aroſe from a want of proper diſtinction between the true ſimple inflammable air or *hydrogen*, as it is called in modern nomenclature, and the various modifications of hydrogen holding carbon and other ſubſtances in ſolution, and alſo that other inflammable air (diſcovered by Dr. Prieſtley and explained by Mr. Cruikſhank) which conſiſts ſimply of carbon in a low ſtate of oxygenation, already deſcribed under the article CARBONOUS OXYD. A due attention to theſe ſources of error will enable us to reconcile many of the apparent contradictions that appear on this ſubject in the relations of Prieſtley, Lavoiſier, Kirwan, and other eminent chemiſts.

Referring to the articles of PHLOGISTON and WATER the exact details of the experiments by which the leading property of *hydrogen*, that is (as its name implies) the *generator of water*, appears to be fully eſtabliſhed, we ſhall here merely give the principal characters of this important gas.

Hydrogen gas is obtained in a ſtate of conſiderable purity only by means of metals, and with particular eaſe and convenience from iron and zinc, either by the united action of the muriatic or ſulphuric acid and water, or ſimply by water coming in contact with theſe metals when ſtrongly heated. But beſides theſe ſources, almoſt every inflammable vegetable and animal ſubſtance contains abundance of hydrogen, ſuch as oil, alcohol, &c. &c. which is readily given out by heat, by electricity, and in a number of other modes of decompoſition, and when burning in the air conſtitutes the *flame* which theſe ſubſtances produce on ignition. Therefore the character of *generator of flame* is highly characteriſtic of this gas, though by no means ſo excluſively as that of generating water, for phoſphorus, oxyd of carbon, and a few other ſubſtances will produce flame on ignition, but no other known body but hydrogen will produce water. But generally ſpeaking, the preſence of flame is ſufficient to ſuſpect the preſence of hydrogen.

To procure this gas, for experiment, take any quantity of malleable iron, ſuch as iron turnings or clean nails, put them in a bottle with a bent tube, add to them ſome ſulphuric acid diluted with about ten times its bulk of warm water, or muriatic acid leſs dilute, and almoſt immediately the action of the diluted acid will be ſeen by a number of minute bubbles detaching themſelves from the ſurface of the metal, and riſing rapidly to the top of the liquor. Theſe bubbles are hydrogen gas, the firſt portions of which ſhould be allowed to eſcape, being mixed with the air of the veſſel, after which it may be collected in proper veſſels over water or mercury for uſe. By keeping up a very moderate warmth, and occaſionally adding more acid as the former portion becomes ſaturated, the ſame materials will continue giving out the gas for a great length of time. After ſaturation the liquor is a dilute ſulphat or muriat of iron, according to the acid employed. It is of uſe to ſhake the bottle occaſionally to detach a cruſt of oxyd of iron, which is apt to form on the ſurface of the metal when the ſulphuric acid is uſed and impedes the further action of the acid. The preciſe degree of dilution of the acid is of little conſequence. The explanation of this proceſs according to the antiphlogiſtic ſyſtem is, that the iron firſt decompoſes part of the water, unites with its oxygen and becomes an oxyd of iron, whilſt the hydrogen, the other conſtituent of the water, flies off in the form of gas: and the oxyd of iron then diſſolves in the acid. So that the ſolution is properly a ſulphated or muriated *oxyd of iron*. If it be aſked what it is that ſuddenly determines or impels the iron to decompoſe the water, it can only (as far as our preſent know-

ledge reaches) be referred to that frequent but paradoxical explanation of an affinity beginning to act before one of the ſubſtances that are the ſubjects of that affinity is fully formed; that is to ſay, in the preſent inſtance, it is ſuppoſed to be the affinity between the ſulphuric or muriatic acid and the *oxyd of iron* that cauſes the *metallic iron* to convert itſelf into an oxyd, by the medium of the decompoſed water.

Hydrogen gas may alſo be procured in great abundance and with much more eaſe and rapidity by ſubſtituting zinc for iron in the above manner. The ſulphuric or muriatic acid employed will bear full as much dilution. The zinc need not be minutely divided, no more being required than to form it into ſmall lumps by pouring it when melted into cold water. The hydrogen gas begins to riſe copiouſly the moment the zinc touches the acid, and more rapidly with the muriatic than the ſulphuric.

Another method of procuring hydrogen gas in great abundance and purity is by ſending the ſteam of boiling water over red hot iron confined in a tube of earth or iron. On account of the brittleneſs and poroſity of earthen tubes thoſe of iron are preferred. A portion of a gun-barrel open at each end is generally employed. This is long enough to be thruſt through the middle of a furnace, and to project ſome inches out of it at each end. *(See in the Appendix the article* HYDROGEN, *Apparatus for.* The centre of the barrel is filled with iron wire, or better with iron *turnings*, and heated red-hot. When hot, the vapour of boiling water is ſent through them from a ſmall retort half full of water, heated by a lamp and luted to one end of the barrel, and in its paſſage it is decompoſed by the multiplied contact of the ſurface of the red-hot iron; and a copious ſtream of hydrogen gas iſſues out through the other end of the barrel, the bore of which is leſſened by luting to it a narrow curved tube, which conveys the gas to the veſſels appointed to receive it. The iron turnings after this operation are found to retain their ſhape, but to be converted totally or partially, into a brittle duſky lead-coloured gloſſy oxyd, which readily crumbles down under the finger. The inner ſurface of the barrel is alſo changed in the ſame manner to a ſmall depth, and therefore hydrogen would be procured ſimply by ſending the ſteam through the clean hot barrel as long as any of the ſurface remained in the metallic ſtate. By frequent uſe, the barrel becomes corroded quite through, but if the inſide is not ſcraped it will laſt a conſiderable time. The outſide alſo ſhould be coated thinly with clay to prevent it from ſcaling when in the fire.

In this caſe as in the former, the hydrogen is produced and the metal oxydated by the decompoſed water, and the increaſed heat is the circumſtance which determines the firſt decompoſition.

This decompoſition of water by iron will take place even in the common temperature ſimply by moiſtening iron filings and keeping them in this ſtate for a conſiderable length of time. The oxyd produced in this inſtance however, if the proceſs is carried on in the open air, is generally united with a portion of carbonic acid.

Zinc when red-hot will decompoſe water in the ſame way as iron, but the proceſs is not ſo eaſily managed on account of the fuſion of the zinc which prevents that extenſive ſurface for action which the iron turnings preſent.

Hydrogen gas has certain differences in ſome of its ſenſible properties, according to the way in which it is procured. When obtained from iron or zinc by means of the acids it has always a peculiar and fetid ſmell, and as Dr. Prieſtley has obſerved, if the production be very rapid, the gas from iron depoſits an ochery film on water over which it ſtands for ſome time, and that from zinc depoſits a white film. It is alſo in general heavier when obtained by means of the acids, than ſimply by paſſing water over hot iron, and in the latter caſe it has much leſs ſmell. On the whole however its *chemical* properties, in whatever of theſe ways it is obtained, if not mixed with atmoſpherical air, are ſufficiently uniform to be deſcribed in common.

Hydrogen gas is an inviſible elaſtic air uncondenſible by any known cold, and is the only form in which pure hydrogen has ever been exhibited. Its ſpecific gravity, as juſt mentioned, varies conſiderably according to the mode in which it has been procured. In general when pure it is from ſix to ten or even twelve times lighter than common air, ſo that eight times may be taken as a general average. It is therefore by far the lighteſt of all the gaſſeous fluids.

The levity of hydrogen is ſhewn in an entertaining manner by filling a bladder with it, either pure or even largely mixed with common air, fixing the bowl of a tobacco-pipe to the orifice of the bladder, dipping the bowl in ſoaped water, and by ſqueezing the bladder thus blowing ſoap bubbles of hydrogen, imitating balloons, which as ſoon as they are ſet at liberty riſe

rapidly to the ceiling of the room and burſt by ſtriking againſt it.

It is incapable, of itſelf, of ſupporting combuſtion for a moment, a lighted taper dipped in it being immediately extinguiſhed. But when pure hydrogen is put in contact with common air or ſtill more with oxygen, and the ſurface of contact touched with a lighted taper or a red-hot iron, it immediately kindles at this place with a ſlight ſnapping noiſe, and burns with a faint blueiſh-white flame without any ſmoke and ſcarcely viſible in the day time, and continues to burn gradually as long as the contact of air is continued, till the whole is conſumed. This is amuſingly ſhewn by filling a long-necked retort or long tube with pure hydrogen, placing it with the open end downwards (by which the gas on account of its levity is prevented from eſcaping) and kindling it with a taper. A ring of faint blue flame immediately appears at the open mouth, and continues ſlowly to travel up the tube till the whole is burnt out. If during the combuſtion the tube is ſuddenly turned up, the remaining hydrogen riſes through the ring of flame, forming a large and ſudden flaſh, and is immediately exhauſted.

The combuſtion of pure hydrogen therefore is perfectly tranquil and progreſſive through the maſs following the progreſſive contact of air, but if it be previouſly mixed with common air (or ſtill more ſtrikingly with oxygen) and agitated, and a lighted taper then applied, the whole takes fire inſtantly and burns with a large blue flaſh attended with a pretty violent exploſion relatively to the quantity of materials. The electric ſpark kindles this mixture as well as a lighted body. It is on account of this property of ſudden combuſtion with exploſion that care ſhould be taken not to kindle any portion of a large quantity of hydrogen, through however ſmall an orifice, before the operator is ſure of the purity of the gas within, for if it be mixed with any ſenſible quantity of oxygen, the flame inſtantly communicates to the whole maſs, and a dangerous exploſion might enſue. The force and danger of exploſion is of courſe regulated (other things being the ſame) by the degree in which the gas is confined by the veſſel in which it is made. Thus a common phial, holding half a pint of a mixture of hydrogen and common air in due proportions, will not burſt by being kindled at the mouth, much of the force ſpending itſelf at the open orifice; and even, if the phial is ſtout, the ſame quantity of hydrogen and oxygen will hardly burſt by the exploſion, though as loud as that of a common gun; whereas a very few inches of the ſame mixture confined in a very thick and cloſe glaſs tube and fired by the electric ſpark, will often ſhiver it to pieces.

The proportion of oxygen required for the perfect combuſtion of hydrogen, is about one part in bulk of oxygen to two and a half of hydrogen, ſuppoſing each to be pure, or more accurately 85 parts *by weight* of oxygen to 15 of hydrogen. If common air be uſed, the proportions acquired for compleat combuſtion are about 6, in bulk, of common air, to 2 of hydrogen. After exploſion the bulk of the whole is reduced to about 5 parts, and is chiefly the azotic reſidue of the common air, which appears to be quite paſſive in this operation.

The great circumſtances which diſtinguiſh the combuſtion of hydrogen whether ſlowly or by ſudden exploſion, are the total deſtruction of the two gaſſes, relatively to their gaſſeous form, the entire abſence of all viſible vapour or ſmoke, and eſpecially the production of a quantity of moiſture, which precipitates in the form of a thick dew on the ſides of the veſſel wherein the combuſtion is carried on, and ſoon collects in ſufficient quantity to trickle down in evident drops that continue as long as the proceſs is going on. Theſe drops when collected and examined by every chemical teſt are found to be, when the gaſſes are as pure as poſſible, nothing but water.

The particulars of many moſt laborious and accurate experiments that prove this important fact, with the circumſtances under which apparently contradictory reſults have been obtained, will be further mentioned under the article WATER.

Inflammable air proves almoſt inſtantly fatal to ſmall animals introduced in it, as was aſcertained by the experiments of Dr. Prieſtley. Scheele however found that he could reſpire the ſame quantity of this air in and out of a bladder alternately for ſeveral times, without material inconvenience. Many other experiments of Fontana[a] on this ſubject prove, that this is owing to the great dilution which it undergoes in the latter caſe, by mixing with the large quantity of common air always preſent in the lungs; whereas when a ſmall animal is immerſed in an atmoſphere of hydrogen, the air in its lungs makes no ſenſible proportion to the hydrogen. Both theſe were proved by examining each air by nitrous gas, which does not in the leaſt diminiſh in bulk with hydrogen,

[a] Phil Tranſ. vol. 69.

but largely in common air on account of its oxygen. Pure hydrogen therefore does not appear poſitively noxious as the carburetted hydrogen, but only negatively ſo, as not containing any gas fit for reſpiration. Fontana expreſſes the feeling of a peculiar and extremely light and pleaſurable ſenſation on the firſt inſpiration of hydrogen, but by raſhly perſevering in repeatedly breathing it, vertigo, ſwooning, and dangerous oppreſſion of the lungs come on.

Hydrogen is not ſenſibly altered by being kept at reſt over water, nor is it readily abſorbed by it, but by agitation Dr. Prieſtley cauſed water to take up about a thirteenth of its bulk, which was again expelled by heat unaltered. Preſſure combined with agitation will cauſe a much greater abſorption. Mr. W. Henry however gives the quantity of pure hydrogen abſorbable by 100 cubic inches of water at the heat of 60°. by mere agitation and common preſſure to be only 1.53 or about $\frac{1}{65}$. [b]

One of the moſt ſtriking properties which hydrogen exhibits is that of reducing metallic oxyds to the reguline or nearly reguline ſtate. This is effected by the union of the hydrogen with the oxygen of the metallic oxyd, in conſequence of which the hydrogen loſes its gaſeous form, and with the oxygen produces water. The metallic reduction by hydrogen appears to have been firſt noticed by Dr. Prieſtley, but the conſequent production of water in theſe caſes was ſuggeſted by the moſt important reſearches of Mr. Cavendiſh on the union of hydrogen and oxygen.

The firſt direct experiment on metallic reduction by hydrogen made by Dr. Prieſtley, aroſe out of the ſingular fact, alſo remarked by him, of the blackening of flint-glaſs tubes ſimply by being heated red-hot when containing hydrogen gas. Dr. P. found this to happen invariably with *flint-glaſs* under every variety of circumſtances, but not with *green-glaſs*, and as the ſtriking difference between the two is that the former contains oxyd of lead but not the latter, it was concluded with reaſon that the blackneſs was owing to the reduction of that metal.

This fact led to the following beautiful ſet of experiments: [c] Some minium was put on an earthen ſupport (a bit of crucible) and incloſed in a thin glaſs receiver filled with hydrogen gas ſtanding over water. The rays from a lens were tranſmitted through a receiver (applied with caution) and concentrated on the minium ſo as to heat it red-hot. It then ſoon became black and ran in the form of metallic lead, at the ſame time that the gas diminiſhed rapidly, as was ſhewn by the rapid riſe of the water within the receiver. Several of the other metallic oxyds heated in the ſame way diminiſhed the quantity of hydrogen and were themſelves reduced to or towards the metallic ſtate. The oxyds of tin, biſmuth and ſilver ſucceeded very well; copper, iron and cobalt, imperfectly. The copper in this inſtance was brittle, but became perfect copper when again fuſed with borax. The eſſential circumſtance of the formation of water in theſe inſtances was not at firſt noticed, the actual quantity being very ſmall and mingling with the maſs of water with which the gas was confined. But on repeating the experiment over mercury ſome water was always detected, which was more than could well be accounted for from the accidental moiſture of the metallic oxyd.

The ſame reduction of the oxyd of lead was found to take place equally well in ammoniacal gas as in hydrogen, (for ammonia is compoſed of azot and hydrogen) and this ſtrikingly confirms the other experiments. From $5\frac{1}{2}$ ounce meaſures of ammoniacal gas, Dr. Prieſtley got, by means of heating litharge in it, 17 grains of lead, beſides ſome that was diſſolved in the mercury confining the gas. The reſidue was $2\frac{1}{2}$ ounce meaſures of *azotic gas*, the other conſtituent of the ammonia.

The reduction of the metals by hydrogen is well ſhewn by Mrs. Fulhame's [d] experiments on this ſubject. The object of the experiments was to imitate gold and ſilver brocade by the very ingenious idea of moiſtening the ſilk or other ſubſtance to be brocaded with the ſolution of gold or ſilver or any other metal, and to revive the metal in the pores of the ſilk by expoſing it to ſome reducing operation. Among others the effect of a current of hydrogen gas was tried. It was found eſſential to the reduction that the cloth or ſilk ſhould always be kept moiſt while in contact with the hydrogen, otherwiſe the reducing proceſs is very languid and imperfect.

A bit of ſilk was immerſed in a dilute nitro-muriat of gold and dried in the air. It was then expoſed for half an hour, *dry*, to a current of hydrogen gas, but no ſigns of reduction appeared: but a ſimilar bit expoſed in the ſame way when *wet* ſhewed inſtant ſigns of reduction, the yellow colour of the ſolution began to turn green, and very ſoon a film of reduced gold glittered on the ſurface oppoſite to the gas.

[b] Phil. Tranſ. vol. 93, p. 276. [c] Prieſtley on Air, vol. 1, p. 250. [d] Fulhame's Eſſay on Combuſtion.

Shortly after a beautiful blue ſpot fringed with orange and purple appeared in the middle of the ſilk. The ſolution of gold ſhould be firſt evaporated to dryneſs and then rediſſolved in diſtilled water to get rid of the exceſs of acid.

A bit of ſilk dipped in a dilute nitrat of ſilver and expoſed wet to a current of hydrogen ſoon became brown, which colour gradually deepened and the oppoſite ſurface of the ſilk was coated with a film of reduced ſilver.

Platina was reduced in the ſame way.

Mercury was reduced very ſpeedily and beautifully without any preceding brown ſpot, as in the foregoing inſtances.

Moſt of the other metallic ſolutions were reduced in a ſimilar manner, but the thin metallic pellicle very ſpeedily tarniſhed.

Hydrogen exerciſes its deoxygenating powers on many other ſubſtances. Dr. Prieſtley found ſulphuric acid to be compleatly decompoſed by it, aſſiſted by heat, and to depoſit ſulphur. For this purpoſe he threw the focus of a lens on a quantity of ſulphuric acid contained in a hollow veſſel, and the whole incloſed in a large receiver full of hydrogen gas and evaporated the acid to dryneſs. In conſequence, the receiver became incruſted with a white film, of which enough could be ſcraped off to produce the blue flame and ſmell of true ſulphur when laid on a hot iron.

A ſingular and amuſing property has lately been found in hydrogen. Let a bottle be filled nearly full of the materials to produce this gas rapidly (for which purpoſe bits of zinc and dilute ſulphuric or muriatic acid are beſt), and let this bottle be cloſed with a cork into which is cemented a bit of tobacco-pipe or a glaſs tube drawn out into a ſmall bore, and kindle the gas as it iſſues through the tube, waiting a ſhort time however leſt any remaining atmoſpherical air in the bottle produce an exploſion. This will give a vigorous jet of fire about half an inch to an inch long. Then provide a portion of a ſtraight glaſs tube of about a foot in length, more or leſs, and open at both ends, and hold it vertically over the flame ſo that it may juſt enter the lower end of the tube, and immediately an extremely loud ſhrill ſound will be heard, producing a vibration almoſt painful to the ears and very ſenſible to the hand that holds the tube. At the ſame time the jet of flame will be drawn up the tube, as through a chimney, with extreme vehemence, and if thruſt up a little higher, it will be blown out by the ſtrength of the draught. Different lengths and diameters of tubes may be uſed to produce different varieties of tone at pleaſure. No other jet of burning vapour will produce this effect, which therefore ſeems to be owing, as Dr. de la Rive[a] has ſuggeſted, to the very rapid vacuum which the burning hydrogen occaſions, which, aſſiſted by the heat, cauſes ſo powerful a draught of the lower air through the tube.

The only uſe to which hydrogen gas has been applied is that of filling balloons. For this purpoſe it has generally been found to be cheaper and more commodious to uſe dilute ſulphuric acid and iron turnings or refuſe bits of various kinds, and ſometimes zinc, though more rarely, becauſe iron is cheaper, and the reſiduary ſulphat of iron is a more ſaleable article than the ſulphat of zinc. To fill a balloon, the materials are put into a number of wooden caſks, from each of which proceeds a tin tube that conveys the gas to a common channel, which is a tube of well varniſhed canvas or leather, which opens in the belly of the balloon. In France, at the military balloon eſtabliſhment at Verdun, the production of hydrogen by paſſing ſteam over red-hot iron in large cylinders was adopted.

Hydrogen diſſolves a variety of ſubſtances with which it comes in contact, particularly at the moment of its production or its *naſcent* ſtate when heated ſtrongly with them. It is not improbable that as commonly prepared it may volatilize and hold in gaſſeous ſolution a portion of iron or zinc, to which may be aſcribed part of its fetid ſmell, and it is certain that it will thus diſſolve a very ſenſible portion of *Arſenic*, which it again in part depoſits. The other and more important combinations of hydrogen are thoſe in which it holds diſſolved a portion of *Sulphur*, of *Phoſphorus* and of *Carbon*. Theſe gaſſes are deſcribed reſpectively under the articles *Arſenicated Hydrogen*, *Sulphuretted Hydrogen*, *Phoſphuretted Hydrogen*, and *Carburetted Hydrogen (which ſee.)*

HYDRO-SULPHURET is the combination of ſulphuretted hydrogen with an alkaline, earthy or metallic baſe. See SULPHURETTED HYDROGEN.

HYDROTHIONIC ACID is a term given by ſome German chemiſts of eminence, to SULPHURETTED HYDROGEN, *(which ſee)*.

HYDROMETER is an inſtrument whereby to aſcertain the ſpecific gravities of bodies. *(See the Appendix.)*

HYDROPHANE. See OPAL.

[a] Phil. Journ.

I

ICE. See FREEZING.

ICELAND SPAR. See LIMESTONE.

IDOCRASE. See VESUVIAN.

INCINERATION, is nearly ſynonimous with *Calcination*, and means the burning of any ſubſtance to aſhes.

INDIGO OR ANIL.

This moſt valuable pigment, which forms ſo important a part of Weſt and Eaſt Indian commerce, is uſually brought over in ſquare or oblong cakes of an intenſe blue colour, almoſt black in maſs, brittle and friable, light when of a good quality, and of a very peculiar and diſagreeable ſmell.

Indigo is uſually reckoned by chemiſts as a kind of fecula, but of a very peculiar nature not exactly reſembling any other known ſubſtance. It is prepared by fermentation of the leaves of the indigo-plant, of which the method is ſhortly the following:[a b]

There are three principal varieties of the indigo-plant known and uſed in the Weſt Indies, in Carolina, and the reſt of the American continent, from each of which much indigo is obtained: one variety, which is the ſmalleſt, is the *Indigofera Tinctoria*, Linn. (called by the French *Indigo-franc*,) which is a delicate plant rather difficult of cultivation, but which yields indigo in abundance and with eaſe: a ſecond variety is the *Indigofera Argentea*, Linn. (*Indigo bâtard.*) which is hardy and eaſily cultivated, and gives a very fine indigo: and a third variety is the *Indigofera Diſperma*, Linn. (*Indigo Guatimala*), which much reſembles the laſt mentioned.

The ſeed of the plant is ſown in about March or April, at Saint Domingo, and the plant comes into flower about three months afterwards, at which time it is in full maturity and is then cut. If it is gathered before flowering, the indigo which it yields is of a finer colour, but much leſs in quantity.

The chief apparatus of an indigo-houſe conſiſts of three wooden vats, of different ſizes, and arranged on different levels, ſo that the contents of the firſt may flow into the ſecond, and of the ſecond into the third. The firſt is the ſteeping vat, in which the plant ferments with water; the ſecond is a vat in which the thick fermented maſs is beaten violently by machinery; and the third is that in which the indigo ſettles when fully formed.

The plant being cut, is firſt laid into the ſteeping vat ſo as to fill it entirely but without preſſing, and is covered about three inches with water. A frame of heavy wooden bars is then laid on the vat to keep the plant down when working. Fermentation ſoon begins in theſe hot climates, and the whole contents of the vat ſwell and foam prodigiouſly like a wine vat in full action, and with diſengagement of large bubbles of gas, which as they burſt appear of a lively green, and tinge the whole vat of the ſame colour. When this proceſs is at the higheſt the fermenting maſs is alſo covered with a brilliant *copper-coloured* ſcum, which paſſes into violet towards the end, but the pulp and liquor beneath remain green.

The gas given off during the proceſs is inflammable and readily takes fire by applying a lighted candle, and the heaving of the ſcum is ſo powerful as often to lift up the heavy wooden frame above mentioned.

The fermentation is known to be carried on long enough by taking ſamples of the fermenting maſs at different times, which when perfect appears as a liquor holding ſuſpended a diſtinct green pulp, that by a little agitation ſpeedily and compleatly ſeparates and falls to the bottom of the cup, leaving a clear ſupernatant gold coloured liquor. Much practical ſkill is required to ſeize the exact point when to ſtop the fermentation, which requires in general from twelve to ſixteen hours.

The whole turbid green liquor is then let out of the fermenting or ſteeping vat and paſſes into another veſſel where it is violently beaten either by the repeated fall of buckets, or by a more complicated mechanical contrivance. This has the effect of checking the further fermentation, of preventing putridity, and eſpecially of promoting in a remarkable degree the ſeparation of the *grain* as it is called, or the dark-coloured granular pulp which is the indigo. The whole liquor and pulp during the proceſs change from green to deep blue by the agitation. It is alſo the cuſtom in many places to add lime-water to the pulp at this time, which is thought to haſten the graining. A large quantity of air-bubbles is alſo expelled by the beating.

When the grain ſeparates readily and compleatly by a little reſt from the liquor that holds it ſuſpended, the beating is ſtopped, and the grain ſlowly ſubſides. The ſupernatant liquor is then drawn off by cocks and ſuffered to run to waſte, carefully avoiding to mix it with any brook or drinking pond which it

[a] Nouv. Dict. d'Hiſt. Nat. art. Indigo. [b] Bancroft on Colours.

would poiſon and render dangerous for animals to uſe. The thick dark-blue pulp is then let off into the loweſt vat, out of which it is laded into common ſacks, which when full are hung up that the water may drain off, the indigo itſelf being too thick to paſs through. The indigo is then transferred to ſmall wooden boxes where it is further dried by alternate expoſure to ſun and ſhade, and as it becomes ſolid is cut into ſquare cakes. It is not yet perfect however, for if exported in this ſtate it would mould and ſpoil, ſo that a ſecond fermentation is neceſſary. For this, the cakes are heaped in a caſk, and ſimply ſuffered to remain for about three weeks. During this time it undergoes a kind of fermentation, heats, ſweats at the ſurface, gives out a diſagreeable ſmell, and is covered with a fine white meal. It is then taken out and dried in the ſhade for five or ſix days when it is quite compleat.

This, with ſome ſlight variations in different plantations, is the general way of preparing indigo, which therefore may be defined to be a fecula or pulverulent pulp ſeparated from the fibre and juices of the entire plant by fermentation, and materially changed by the proceſs, and doubtleſs by expoſure to the atmoſphere, ſo as to paſs from green to a deep blue, and from a ſoluble to an inſoluble ſtate.

Indigo is generally packed in cheſts of about two hundred pounds weight each. The very fine kind that comes from Guatimala is uſually wrapped up in goats' ſkins.

Very ſingular chemical properties have been diſcovered in indigo by different experimenters, among whom may be particularly mentioned Bergman, Hauſſman,[c] and Bancroft. The moſt ſingular circumſtance concerning indigo, is the inſolubility of the blue colouring part in every *ſimple* menſtruum hitherto known (except the ſulphuric acid) without ſuch an alteration as entirely deſtroys the colour for which it is ſo much valued.

Water boiled long upon indigo (the fineſt and pureſt kind being always ſuppoſed, as the ordinary ſorts are largely adulterated) diſſolves about a ninth according to Bergman, or a twelfth according to Quatremere, of the weight.[d] The ſolution is of a reddiſh brown colour, and contains what may be called the extractive part, but the colouring portion remains abſolutely unaltered, and ſomewhat of a brighter hue. The watery ſolution is aſtringent and mucilaginous.

Alcohol diſſoves a ſtill ſmaller portion than water, and the colouring part remains equally untouched. Ether has nearly the ſame effect. Neither the fixed nor the volatile oils have any effect on indigo.

The ſulphuric acid is the only ſingle agent that diſſolves indigo without deſtroying its colour, and its application as a dye, in which circumſtance it is called *Saxon blue*, has been mentioned under the article *Dyeing*.

The acid ſhould be tolerably concentrated to diſſolve the indigo, and it may be uſed quite concentrated without detriment, at leaſt in ſmall quantities. A moderate heat much aſſiſts its action, but if too high, the indigo becomes partially burnt or charred, ſulphuric acid gas is given out, and all the portion thus altered remains inſoluble and is ſpoilt. The following recipe for the ſulphat of indigo, or Saxon blue, is given by Mr. Woulfe.[e] Mix one ounce of the beſt powdered indigo with four ounces of oil of vitriol, in a glaſs matraſs, and digeſt it for one hour in the heat of boiling water, ſhaking the mixture ſeveral times, then add twelve ounces of water to it, ſtir the whole well, and when cold filter it. This produces a very rich deep blue colour, of a much brighter hue than any of the other ſolutions of this pigment, but not a faſt colour upon animal or vegetable fibre. The colouring power is very great, a few drops of this ſolution giving a very ſenſible blueneſs to a conſiderable bulk of water.

The nitric acid acts upon indigo with great vehemence, and in a very ſingular manner. If on a dram or two of finely powdered indigo be poured about an ounce of fuming nitrous acid, in a ſhort time the mixture heats violently, ſends forth a copious flow of nitrous gas, with a ſtream of ſparks, and the whole ends with burſting into flame. When diluted, the acid acts much more mildly, but always with the entire deſtruction of the blue colour, and in its ſtead produces a yellow aſtringent liquor, which is pretty faſt upon cotton or cloth dipped in it. This ſolution however is uſeleſs in manufacture. Mr. Hauſſman has examined with ſome minuteneſs the action of nitric acid on indigo.[f] On adding at intervals four ounces of powdered indigo to 16 ounces of common aqua fortis heated a little, a great ſwelling and diſengagement of nitrous gas took place, and a coagulum was left, which when waſhed with cold water, formed a brown, viſcous, and very brittle maſs, in appearance like a gum-reſin, diſſolving in alcohol with eaſe, but not eaſily in water, except

[c] Jour. Phyſ. for 1788. [d] Jour. Phyſ. tom. x & xi. [e] Phil. Tranſ. vol. lxi. [f] Journ. Phyſ. for 1788.

in a large doſe, and hot. The acid liquor in which the coagulum was formed, when evaporated and cooled, let fall more of the ſame bitter reſinous matter, after which it depoſited a large quantity of cryſtals reſembling oxalic acid in appearance, but bitter to the taſte, and totally differing from it in chemical properties. The nature of theſe cryſtals is not well known. An anonymous writer in Nicholſon's Journal,[s] on repeating the above experiments, and uſing a very large quantity of acid, by repeated diſtillations nearly deſtroyed the reſinous matter, and obtained in the receiver a clear yellow liquor, ſtrongly ſmelling of bitter almonds, which ſuggeſted the idea of its being pruſſic acid; however after adding alkali to it and ſulphat of iron, no blue precipitate was produced.

The oxymuriatic acid acts but feebly on indigo in decompoſing or diſorganizing it, but deſtroys the blue colour totally and ſpeedily. Hence the ſulphat of indigo has ingeniouſly been applied as a meaſure of the intenſity of the bleaching power of the oxymuriatic acid.

None of the other acids exert any apparent action on the colouring matter of indigo.

None of the alkalies, nor alkaline earths, either mild or carbonated, when uſed alone, have any action whatever on indigo in its blue or perfect ſtate. But to effect a ſolution of it in alkalies, it is neceſſary to uſe ſome addition, which appears firſt to change the indigo, and bring it back to a ſtate reſembling the recent pulp during the proceſs of manufacture. This at leaſt is made probable by the change of colour that precedes the ſolution in alkalies, and appears an eſſential circumſtance, and this change is from blue to green of various ſhades, with a brilliant pellicle on the ſurface, of the colour and gloſs of reguline copper, or rather brighter. This ſame change, but in a reverſe order, takes place in the fermentation of the plant, and proceſs of manufacture; that is, the colour is at firſt green, with a copper-coloured pellicle, and finally blue.

Indigo not only requires to be changed from the blue to the green ſtate, before it will diſſolve in alkalies, but when the ſolution is made, it only remains diſſolved, as long as it continues green, or greeniſh yellow; for when by any means it reſumes its blue ſtate, it immediately becomes inſoluble, and ſeparates from the alkaline liquor in form of a dark blue mud, or ſediment. Expoſure to the atmoſphere regenerates blue indigo in a remarkable manner, ſo that if a drop of the ſolution be poured on paper, the ſurface turns from green and yellow to blue in a very few ſeconds, which laſt colour may be again removed (but irrecoverably ſo) by the oxymuriatic acid. From theſe and other circumſtances, Dr. Bancroft infers, that the cauſe of the change ariſes from the different degree of oxygenation, the green being in the loweſt ſtate of oxygenation, and the blue in the higheſt. The ſubſtances that form proper additions to enable alkalies to diſſolve indigo are very numerous, and very diſcordant in their nature, for not only have the metallic ſub-oxyds this power, (as might be expected) but even almoſt every ſoluble vegetable matter has the ſame, ſuch as ſugar, raiſins, bran, &c. &c. A very ſimple, and efficacious way of diſſolving indigo, is by means of the oxyd of tin, for which, let ſome well ſaturated muriat of tin be ſuper-ſaturated with potaſh, ſo that the precipitate at firſt formed, may be rediſſolved, and the ſolution converted into an alkaline one, after which, indigo will diſſolve in it readily, and aſſume almoſt inſtantly a deep green colour.

The particular methods of preparing theſe ſolutions in the indigo vats, for the uſe of the dyer, are deſcribed ſufficiently under the article DYEING.

The analyſis of indigo by fire only, affords but little inſight into its compoſition. When diſtilled *per ſe*, ſome ammonia and a peculiar oil riſe, and if afterwards burnt away, nothing remains but a very ſmall portion of a very light brown powder or aſh. This is a tolerable teſt of its goodneſs, as there is hardly any vegetable that leaves ſo ſmall an aſh.

The immenſe uſe of indigo in dyeing, has already been fully noticed. At preſent by far the greater part of what is employed in England, comes directly from the Eaſt Indies.

INFLAMMABLE AIR. See HYDROGEN.

INFLAMMATION.

Inflammation may be defined to be combuſtion attended with flame. To what is given on this ſubject under the article CALORIC, ſome obſervations may here be added on the ſpontaneous inflammation of various ſubſtances, on which ſome important facts have been collected.

Some of the cauſes of the ſpontaneous inflammation of combuſtible ſubſtances are too well known to require to be enlarged upon. Of this kind are friction, the heat produced by the ſlacking of lime when in contact with combuſtible matter, the fermentation of hay, of dunghills, &c.

[s] Vol. 3, 4to. p. 480.

But beſides theſe more common cauſes, experience has ſhewn that many vegetable ſubſtances, highly dried and heaped together, will heat, ſcorch, and at laſt burſt into flame. Of theſe, the moſt remarkable is a mixture of the expreſſed oil of the farinaceous ſeeds, as rape or linſeed oil, with almoſt any other dry vegetable fibre, ſuch as hemp, cotton, matting, &c. and ſtill more, if alſo united with lamp-black, or any carbonaceous ſubſtance. Theſe mixtures if kept for a time undiſturbed in cloſe bundles, and in a warm temperature, even in ſmall quantities, will often heat, and burn with a ſmouldering fire for ſome hours, and if air is admitted freely, will then burſt into flame. To this without doubt may be attributed ſeveral accidental conflagrations in ſtorehouſes, and places where quantities of theſe ſubſtances are kept, as has been proved by direct experiment.

The moſt important of theſe were made by Mr. Georgi, and a committee of the Royal Academy at Peterſburgh, in the year 1781, in conſequence of the deſtruction by fire, of a frigate in the harbour of Cronſtadt; the conflagration of a large hemp magazine in the ſame place in the ſame year; and a ſlight fire on board another frigate, in the ſame port, in the following year.[a]

Theſe accidents led to a very ſtrict examination of the ſubject, by the Ruſſian government, when it came out, that at the time of the ſecond accident, ſeveral parcels of matting, tied with packthread, in which the ſoot of burnt firewood had been mixed with oil, for painting the ſhip, had been lying ſome time on the floor of the cabin whence the fire broke out.

In conſequence of which, the following experiments were made.

Forty pounds of fir-wood ſoot were ſoaked with about 35 pounds of hemp-oil varniſh, and the whole was wrapped up in a mat, and put into a cloſe cabin. In about ſixteen hours it was obſerved to give out a ſmoke, which rapidly increaſed, and when the door was opened, and the air freely admitted, the whole burſt into a flame.

Three pounds of fir-black were mixed with five pounds of hemp-oil varniſh, and the whole bound up in linen, and ſhut up in a cheſt. In ſixteen hours it emitted a very naufeous putrid ſmell and ſteam, and two hours afterwards it was actually on fire, and burnt to aſhes.

In another experiment, the ſame occurrences took place, but not till the end of forty-one hours after the mixture had been made; and in theſe and many ſimilar experiments, they all ſucceeded better, and kindled ſooner on bright, than on rainy days. Chimney ſoot uſed inſtead of lamp-black did not anſwer, nor was any effect produced, when oil of turpentine was ſubſtituted for the hemp or rape oil. In general, it was found, that the accenſion took place more readily with the coarſer and more unctuous fir-black, than with the finer ſorts, but the proportions of the black to the oil, did not appear to be of any great moment.

Sometimes in wet weather, theſe mixtures only became hot for ſome hours, and then cooled again, without actually taking fire.

In all theſe caſes, the ſoot or black was from wood, and not coal.

The preſence of lamp-black, or any other dry carbonaceous matter, is not neceſſary however, for a ſpontaneous inflammation will take place in hemp or cotton, ſimply ſoaked in any of theſe expreſſed oils, when in conſiderable quantity, or under circumſtances favourable to this proceſs, as in very hot weather, or cloſely ſhut up. An accident of this ſort happened at Gainſborough in Lincolnſhire, in July 1794,[b] with a bale of yarn of 120 lb. accidentally ſoaked in rape oil, which after remaining in a warehouſe for ſeveral days, began to ſmoke, to emit a moſt naufeous ſmell, and finally to burſt out in a moſt violent flame.

A ſimilar accident with a very ſmall quantity of the materials, happened at Bombay.[c] A bottle of linſeed oil had been left ſtanding on a cheſt, this had been thrown down by accident, in the night, the oil had run into a cheſt which contained ſome coarſe cotton cloth, and in the morning the cloth was found ſcorching hot, and reduced nearly to tinder, and the wood of the cheſt charred on the inſide.

On ſubſequent trial, a piece of the ſame cloth was ſoaked in oil, ſhut up in a box, and in no longer time than three hours, it was found ſcorching-hot, and on opening the cloth, it burſt into fire.

Similar to this, is the ſpontaneous combuſtion of wool or woolen yarn, which has occaſionally happened when large quantities have been kept heaped up in rooms little aired, and in hot weather. The oil with which wool is dreſſed, which is generally rape oil, appears the chief agent in this combuſtion.

Even high dried oily, or farinaceous matter of any kind, will alone take fire, when placed in circumſtances very favourable to this proceſs.

Rye flour roaſted till half parched, and of

[a] Tooke, Repertory, vol iii. [b] Repertory, vol iii. [c] Phil. Tranſ. vol. 84.

the colour of coffee, and wrapped up in a linen cloth, has been found to heat violently, and to deſtroy the cloth.

Wheat flour, when heated in large quantities, and highly dried, has been known to take fire in hot weather, cauſing accidents in granaries and baker's ſhops.

An accident of this kind is related by Count Morrozzo, in the memoirs of the Turin Academy,[c] to have happened at a flour warehouſe at Turin, containing about 300 ſacks of flour. It began by a violent exploſion on a lamp being brought into the warehouſe, and the whole was ſoon after in flames.

Charcoal alone alſo has been known to take fire in powder-mills, when quantities of it in powder have been kept for ſome time cloſely packed.

Another, and totally different ſpecies of ſpontaneous combuſtion, is that which occurs during the oxygenation or vitriolization of pyrites, or ſulphurets of iron, copper, &c.

A moſt curious, and if it were not well authenticated, a ſcarcely credible ſpecies of ſpontaneous inflammation, is that which has in a few rare inſtances been known to occur in the human body.

It is not quite certain indeed whether the firſt inflammation has been quite ſpontaneous, or cauſed by the approach of a lighted ſubſtance; but in theſe melancholy accidents, the body of the unfortunate ſufferers has been brought to a ſtate of ſuch high combuſtibility, that the flame once kindled, has gone on without other fuel, to the entire deſtruction of every part, (the bones and extremities excepted) and, as appears, attended with actual flame, of a lambent faint light. This change is the more remarkable, as the human body in all its uſual ſtates, both of health and diſeaſe, is ſcarcely at all of itſelf combuſtible, and cannot be reduced to aſhes without the aſſiſtance of a very large pile of faggots, or other fuel, as univerſal experience in the very ancient mode of ſepulture, and the hiſtory of martyrdoms, abundantly ſhews.

The caſes of this human combuſtion on record, have occurred in different countries. Two of them, well authenticated, are recorded in the Philoſophical Tranſactions,[a] and have occurred in England, and a few others in Italy, France, and elſewhere. In all but one, the ſubjects of them have been females rather advanced in life, of indolent habits, and apparently much addicted to ſpirituous liquors. The accident has generally been detected by the penetrating fetid ſmell of burning and ſooty films, which have ſpread to a great diſtance, and the ſufferers have in every inſtance been diſcovered dead, and with the body more or leſs compleatly burnt up, leaving in the burnt parts, only an oily, crumbly, ſooty, and extremely fetid matter. Another circumſtance in which theſe caſes all agree, is the comparative weakneſs of the heat produced by this combuſtion, notwithſtanding the very compleat diſorganization of the body itſelf, ſo that the furniture of the room, wooden chairs, &c. which were found within reach of the burning body, were in many inſtances, abſolutely unhurt, and in others, only ſcorched, but the heat was not ſtrong enough to ſet them actually on fire.

It is impoſſible to give an adequate reaſon for this moſt remarkable change, nor does it ſeem before the very time of the accident to have produced any very ſenſible alteration in the appearance, and the functions of the body,—a moſt aſtoniſhing circumſtance.

With regard to the effect which the uſe of ardent ſpirits is ſuppoſed to have here, it is impoſſible not to imagine that this cauſe may contribute largely to this change; but the inſtances of the abuſe of ſpirits are ſo innumerable, and thoſe of this ſurpriſing combuſtion, are ſo extremely rare, that very little ſatisfaction can be obtained from this explanation.

INFUSION

Is the maceration of any ſubſtance in water, or any other liquid, hot or cold, with a view of extracting its ſoluble parts. The liquid thus impregnated is called *an Infuſion*.

INGOT.

An ingot is a ſmall bar of metal made of a particular form and ſize, (generally a very long parallelopiped) by caſting it in hollowed iron or braſs plates, called *ingot moulds*. It is chiefly to the ſmall bars of gold and ſilver that the term ingot is applied.

INK. *Common writing*.

The preparation of common writing ink, is a ſubject of great importance in technical chemiſtry. A good ink is of a proper conſiſtence to flow freely from the pen, of a full deep black, ſo permanent as to remain for a number of years without materially fading, or becoming illegible, dries very ſoon after writing with it, and does not conſiderably corrode, or ſoften the pen. The baſis of all the common writing inks is the fine black, or dark blue precipitate, formed

[a] Repertory, vol. ii.

[c] Vol. 43 and 64.

by the addition of vegetable aſtringents, and particularly the ſoluble part of the gall-nut, to a ſolution of iron, generally the ſulphat. But as this, if diffuſed in water alone, would ſubſide in a ſhort time, and leave the ſupernatant liquor nearly without colour, the precipitate is kept ſuſpended, by thickening the water with gum arabic, or any other gum mucilage, which alſo gives the ink the due conſiſtence, and enables it to trace a fine ſtroke on the paper without running. Theſe materials therefore, that is, gall-nuts, green vitriol, (ſulphat of iron) gum arabic, and water, are all that are neceſſary for the compoſition of ink, and if they are of good quality, and properly proportioned to each other, every other addition uſually made, adds very little to its perfection.

It is not well aſcertained how ſoon the preſent kind of writing ink came into uſe. It has certainly been employed for many centuries in moſt European countries, but the antient Roman inks were for the moſt part of a totally different compoſition, being made of ſome vegetable carbonaceous matter like lamp-black, diffuſed in a liquor. The Chineſe and many of the other inks uſed by the Oriental nations, are ſtill of this kind.

On the ſubject of the common writing ink, Dr. Lewis[a] has ſo full and ſo accurate an inveſtigation, and his experiments are ſo ſimple and well deviſed, that little elſe can be added to the ſubject in a technical point of view. For a fuller chemical enquiry into the nature of the atramentous precipitate, the reader is referred to the articles GALLIC ACID and IRON.

Dr. Lewis firſt endeavoured to aſcertain the beſt proportion between the galls and the ſulphat of iron, to render the ink permanent; for it is to be obſerved that with almoſt any proportions, if the entire quantity be ſufficient, the ink will be fine and black at firſt, but many of theſe inks if kept for ſome time, eſpecially expoſed to light and air, will grow brown and fade, and the letters made with it will become nearly illegible.

By trying different proportions of galls and ſulphat of iron, it was found that when about in equal quantities (the galls being powdered and boiled fully to extract their ſoluble parts) they appeared to be mutually ſaturated, ſo that the mixed liquors would receive no additional blackneſs from a further doſe of one or the other. This however was only a rough approximation to accuracy, for the ſame effect was produced when either ſubſtance was alſo in a ſmall degree ſuperior in quantity to the other. But Dr. Lewis found that an ink with equal parts of the two, though very black at firſt, changed to a yelloviſh brown upon expoſure to the ſun and air only for a few days. This was again blackened by waſhing with freſh gall-infuſion, and hence it appears a fair inference that the galls are in ſome degree a periſhable ſubſtance, ſo that to enſure durability, a much greater proportion muſt enter into the ink than is required for mere ſaturation in the firſt inſtance. Thus it was found that two parts of galls and one of vitriol, make a much more durable ink than with equal parts, and three of galls with one of vitriol was ſtill more durable. When the galls were encreaſed beyond this point the colour was indeed quite permanent, but it was not of ſo full a black.

The proportion of water or other liquid to the ſolid ingredients will admit of great variation. One part of vitriol, three of galls, and fifty parts of water, gave an ink black enough for common uſe, but the fineſt and blackeſt was made when only ten of water were employed; nor was any deficiency in the gallic acid obſerved after fifteen years, though the water was ſcarcely more than ſufficient to cover the galls, and therefore could hardly be ſuppoſed capable of extracting all the ſoluble part of them, and though the vitriol, from its greater ſolubility, would probably be diſſolved entirely, and thus be in greater proportion than uſual. Other liquors beſides water were tried. Of theſe white wine and vinegar appeared to anſwer ſomewhat better, but any conſiderable proportion of ſpirit of wine, or brandy, obviouſly did harm, owing to the inſolubility of the ſulphat of iron (as of all the other ſulphats) in alcohol, and therefore its diminiſhed ſolubility in any liquor is in proportion to the alcohol it contains. A decoction of logwood uſed inſtead of water, ſenſibly improved the beauty of the colour.

Inſtead of galls other aſtringents were employed, ſuch as ſloes, oak-bark, tormentil root, &c. but though they all gave a good blue-black with the ſalt of iron, none of them was equal to the gall-nut in this reſpect.

Other ſalts of iron were alſo ſubſtituted to the ſulphat. The muriat and nitrat of iron nearly equalled the ſulphat in colour, but proved too corroſive to the paper, and as they were in no reſpect preferable to the ſulphat, there is no reaſon for abandoning it.

Imagining that there muſt be ſome exceſs of

[a] Commerce of Arts.

ſulphuric acid in common ink; to which the fading might be imputed, Dr. L. tried to neutralize it by lime and alkalies, but with manifeſt injury, the colour being rendered thereby extremely fugitive. Another ingenious idea for avoiding the ſuppoſed exceſs of acid, was to ſeparate the black atramentous precipitate, waſh it, and again diffuſe it with water thickened with gum. This did indeed make a very good ink, but with the capital defect of not remaining ſo long ſuſpended in the liquor, and eſpecially of not fixing itſelf to the paper like common ink, but rather only ſlightly adhering like a weak gum varniſh, and was readily waſhed off by water. Hence it appears that the acid of the ſalt of iron acts as a kind of mordant or intermede, between the atramentous precipitate and the paper, and cauſes a degree of chemical union between them: a real advantage which this ſpecies of ink poſſeſſes over all the lamp-black or China inks, which indeed are rather black varniſhes.

With regard to the gummy ingredient, the effect of which is chiefly mechanical, it was found that any other gum-mucilage would anſwer as well, but not glue, iſinglaſs, nor animal jelly of any kind. Beſides as theſe latter putrify by keeping, this alone would be a ſtrong objection.

Sugar is ſometimes added to ink. It makes it flow ſomewhat eaſier from the pen, and gives it when dry a gloſs which is admired by ſome. It has this quality however of making it very ſlow in drying, which in moſt caſes is an inconvenience.

On account of the great improvement to the black atramentous dye produced by adding ſulphat of copper *(See the article Dyeing)*, ſome have recommended this addition to common ink, which is compoſed of the ſame materials; but it does not appear that the ſame advantage is here obtained, and Dr. Lewis thinks it an uſeleſs addition.

From the above obſervations Dr. Lewis gives the following receipt for the compoſition of ink: Put into a ſtone or glaſs bottle, or any other veſſel, three ounces of finely powdered galls, one ounce of green vitriol, one ounce of logwood finely raſped or bruiſed, one ounce of gum arabic, and a quart of ſoft water. Shake the bottle well, and let the ingredients ſtand in a moderately warm place for a week or ten days, ſhaking it frequently in the day. It is then fit for uſe, but a little before it is put into the ink-ſtand, it is better to ſhake the bottle that the colour may be more uniformly diffuſed.

To prevent the ink from moulding, Hoffman recommends half a dozen cloves to be bruiſed with the gum arabic and put into the bottle. This appears an uſeful addition. Inſtead of water alone, where a very fine ink is wanted, white wine or vinegar and water may be uſed.

If the ink be wanted for uſe in a very ſhort time, the galls and logwood may be boiled for half an hour in the water, adding a little more to ſupply the waſte, and the decoction while hot ſtrained off through a cloth, and the gum arabic and cloves, and the ſulphat of iron, both in fine powder, added to the decoction when in the bottle and ſhaken. The ink will then be fit for uſe almoſt immediately after the latter ingredients are diſſolved. It will be improved by adding to the bottle ſome pieces of gall-nut coarſely bruiſed.

Ink kept in a cloſe bottle is always rather pale, but it blackens by expoſure to air in a few hours, and probably in this way the colour is ſomewhat more durable than if it were brought by previous expoſure to its full colour at once.

It has been mentioned that ſugar renders ink ſlow in drying. Advantage is ingeniouſly taken of this property in enabling it to give one, and ſometimes two impreſſions on ſoft paper when ſtrongly preſſed. In this ſimple way letters are copied in merchants counting-houſes, and offices of buſineſs. A little ſugar is mixed with the ink, the written ſheet is laid on the copying preſs, a blank ſheet of porous and damped paper is put over it, and by the preſſure of the machine a perfect fac-ſimile of the writing is ſtruck off, ſufficiently legible for all purpoſes.

This ingenious method ſaves a vaſt quantity of labour uſually beſtowed in copying letters, and beſides prevents all poſſibility of miſtake.

Sometimes the ink of very old writings is ſo much faded by time as to be illegible. Dr. Blagden[b] in his experiments on this ſubject, found that in moſt of theſe the colour might be reſtored, or rather a new body of colour given, by pencilling them over firſt with a ſolution of pruſſiat of potaſh, and then with a dilute acid either ſulphuric or muriatic; or elſe vice-verſa, firſt with the acid and then with the pruſſiat. The acid diſſolves the oxyd of iron of the faded ink, and the pruſſiat precipitates it again of a blue, which reſtores the legibility of the writing. If this be done neatly and blotting paper laid over the letters as faſt as they become viſible, their form will be retained very diſtinctly. Pencilling over the letters with an infuſion of galls alſo reſtores the

[b] Phil. Tranſ. vol. lxxvii.

blackneſs to a certain degree, but not ſo ſpeedily nor ſo completely.

The blackneſs of common ink is almoſt inſtantly and irrevocably deſtroyed by the oxy-muriatic acid, and hence any writing may be effaced by this method completely. To prevent this miſchief, which might often be a ſerious one, ſeveral additions have been propoſed to common ink, of which by far the beſt is lamp-black or charcoal, in impalpable powder, on which the acid has no effect. The lamp-black ſhould be of the leaſt oily kind, as it does not readily mix with the ink, and ſome pains muſt be taken to incorporate them. On this account perhaps common charcoal is preferable. About a quarter of the weight of the vitriol uſed will be amply ſufficient. This will not fade by age.

Ink. *China or Indian.*

The well known and much admired Indian or China ink, is brought over in ſmall oblong cakes, which readily become diffuſed in water by rubbing, and the blackneſs remains ſuſpended in it for a conſiderable time, owing to the extreme ſublety of diviſion of the ſubſtance that gives the colour, and the intimacy with which it is united to the mucilaginous matter that keeps it ſuſpended.

Indian ink does however depoſit the whole of its colour by ſtanding, when it is diffuſed in a conſiderable quantity of water. Dr. Lewis on examining this ſubſtance found that the ink conſiſted of a black ſediment totally inſoluble in water, which appeared to be of the nature of the fineſt lamp-black, and of another ſubſtance ſoluble in water, and which putrefied by keeping, and when evaporated left a tenacious jelly exactly like glue or iſinglaſs. It appears probable therefore that it conſiſts of nothing more than theſe two ingredients, and probably may be imitated with perfect accuracy by uſing a very fine jelly, like iſinglaſs or ſize, and the fineſt lamp-black, and incorporating them thoroughly. The fineſt lamp-black known is made from ivory ſhavings, and thence called *ivory-black*.

Ink. *Printers.*

This is a very ſingular compoſition, partaking much of the nature of an oil varniſh, but differing from it in the quality of adhering firmly to moiſtened paper, and in being to a conſiderable degree ſoluble in ſoap water.

It is, when uſed by the printers, of the conſiſtence of rather thin jelly, ſo that it may be ſmeared over the types readily and thinly, when applied by leather cuſhions, and it dries very ſpeedily on the paper without running through to the other ſide, or paſſing the limits of the letter.

The method of making printer's ink is thus deſcribed by Dr. Lewis.

Ten or twelve gallons of nut oil are ſet over the fire in a large iron pot, and brought to boil. It is then ſtirred with an iron ladle, and whilſt boiling, the inflammable vapour riſing from it either takes fire of itſelf or is kindled, and ſuffered to burn in this way for about half an hour, the pot being partially covered ſo as to regulate the body of the flame, and conſequently the heat communicated to the oil. It is frequently ſtirred during this time that the whole may be heated equally, otherwiſe a part would be charred and the reſt left imperfect. The flame is then extinguiſhed by entirely covering the pot. The oil by this proceſs has much of its unctuous quality deſtroyed, and when cold is of the conſiſtence of ſoft turpentine, and is then called *varniſh*. After this it is made into ink by mixture with the requiſite quantity of lamp-black, of which about 2½ ounces are ſufficient for 16 ounces of the prepared oil. The oil loſes by the boiling about an eighth of its weight, and emits very offenſive fumes. Several other additions are made to the oil during the boiling, ſuch as cruſts of bread, onions, and ſometimes turpentine. Theſe are kept ſecret by the preparers. The intention of them is more effectually to deſtroy part of the unctuous quality of the oil, to give it more body, to enable it to adhere better to the wetted paper, and to ſpread on the types neatly and uniformly.

Beſides theſe additions, others are made by the printers, of which the moſt important is generally underſtood to be a little fine indigo in powder, to improve the beauty of the colour.

For further obſervations on the nature of fixed oils, and the alteration they undergo by heat, ſee the article Oil. *(Fixed.)*

Red printers ink is made by adding to the *Varniſh* about half its weight of vermillion. A little carmine alſo improves the colour.[c]

Inks. Coloured.

Few of theſe are uſed except red ink. The preparation of theſe is very ſimple, conſiſting either of decoctions of the different colouring or dyeing materials in water, and thickened with gum arabic, or of coloured metallic oxyds or inſoluble powders merely diffuſed in gum water. The proportion of gum arabic to be uſed may be the ſame as for black writing ink. All that applies

[c] Encycl. Arts and Metiers. vol. iii. p. 518.

to the fixed or fugitive nature of the ſeveral articles uſed in *dyeing*, may be applied in general to the uſe of the ſame ſubſtances as inks.

Red Ink is uſually made by boiling about two ounces of Brazil wood in a pint of water for a quarter of an hour, and adding to the decoction the requiſite quantity of gum, and about half as much alum. The alum both heightens the colour and makes it leſs fugitive. Probably a little madder would make it more durable.

Blue Ink may be made by diffuſing Pruſſian blue or indigo through ſtrong gum-water.

Yellow Ink may be made by a ſolution of gamboge in gum-water.

Moſt of the common water-colour cakes diffuſed in water, will make ſufficiently good coloured inks for moſt purpoſes.

INKS *Sympathetic or Secret.*

Theſe are all liquids which have ſcarcely any colour in their common ſtate, and therefore when characters are traced with them on paper they are inviſible, or nearly ſo, at firſt, but a colour is given to them either by applying ſome chemical reagent, or by mere heat. A conſiderable number of theſe have been invented, ſome of which may be juſt enumerated.

The ſympathetic ink of cobalt is the beſt known and the moſt ſingular. Any ſolution of this metal that contains muriatic acid in any form becomes green when heated, but returns to a ſtate nearly colourleſs when cold. This alſo will appear and vaniſh alternately by heating or cooling. When the cobalt is pure the colour approaches ſtrongly to blue. *See Cobalt.*

Characters written with lemon-juice are inviſible at firſt, but on ſtrongly heating the paper, the extractive matter of the lemons turns brown, and thus becomes viſible.

Sulphuric acid moderately diluted, anſwers in the ſame way. On heating the paper the water of the acid flies off, the latter becomes thereby concentrated, and acts on the paper, making it brown.

Of the ſecret inks formed by the action of reagents, the metallic ſolutions that are blackened by a liquid ſulphuret, or ſulphuretted hydrogen gas, are the beſt known. Theſe metallic ſolutions are thoſe of lead, ſilver, biſmuth, and mercury.

The acetite of lead is one of the moſt convenient. Letters written by any of theſe ſolutions, are at once blackened and rendered viſible by being wetted with the ſulphuretted ſolution, or more ſlowly by expoſure to the gas. The ſolutions may be very dilute, as the deepening of colour is very powerful.

A weak ſolution of gallic acid diluted to be colourleſs, will alſo be blackened by any ſalt of iron.

Pruſſiat of potaſh will likewiſe become blue by any ſolution of iron.

IRIDIUM. See PLATINA.

IRON. *Ferrum.* Lat. *Fer.* Fr. *Eiſen.* Germ. *Jern.* Dan. *Jarn.* Swed. *Mars.* Alchem.

Iron is a metal, of a bluiſh grey colour, hard, ductile and malleable; capable of acquiring magnetic polarity, and of being welded; ſoluble in the muriatic and moſt other acids; precipitable in the ſtate of Pruſſian blue by a pruſſiated alkali, and aſſuming a deep bluiſh-black colour with infuſion of gall-nut.

§. 1. *Ores of Iron.* [a]

Sp. 1. NATIVE IRON. *Gediegen Eiſen.* Wern. *Fer Natif.* Broch.

Its colour is light ſteel-grey reſembling white caſt iron or platina; but it is generally covered by a thin ſuperficial cruſt of brown oxyd. It occurs branched or cellular. Its luſtre is moderately ſhining and metallic. Its fracture is hackly; it gives a bright ſtreak, may be eaſily cut with a knife; and is perfectly malleable when cold, and in a moderate heat, but at a high temperature it becomes brittle and granular; it is flexible and difficultly frangible. Sp. gr. not exceeding 6.48.

A maſs of native iron, reported by the inhabitants of the country to have fallen from the ſky, was found by Profeſſor Pallas in Siberia. Between the rivulets Ubei and Siſſim, that run into the Jeniſei on the eaſtern ſide, is a mountain containing a rich mine of magnetic iron ore; on the ſame ſide of the mountain where this mine is ſituated, was found lying looſe on the rock the maſs of native iron alluded to, weighing 1680 Ruſſ. lbs. [b] This maſs is cellular, and the cells are either empty or occupied by a tranſparent greeniſh yellow ſubſtance, at firſt taken for fluor ſpar, but which on ſubſequent examination greatly reſembles the chryſolite. [c]

A ſtill larger maſs of native iron was ſeen and deſcribed by Don Rubin de Celis. [d] It is ſituated in the diſtrict of Otumpa, in the Vice-royalty of Peru; its weight is about 15 ton; it is compact externally, and is marked with impreſſions as if of hands and feet, but much larger, and of claws of birds; internally it is full of cavities. It is almoſt imbedded in white clay, and the country round is quite flat and deſtitute of water. Another maſs of iron likened in

[a] Emmerling, Lenz, Kirwan, Jameſon, Hauy, Brochant. [b] Pallas in Phil. Tranſ. lxvi. p. 523. [c] Bournon in Phil. Tranſ. xcii. p. 206. [d] Phil. Tranſ. lxxviii. p. 183.

ſhape to a fallen tree has alſo been ſeen in the ſame territory.

Native iron, in detached maſſes, and of a cellular texture, has alſo been found near Tabor in Bohemia, and in Senegal in Africa.

All theſe ſpecimens of native iron bear a ſtriking reſemblance to each other in their being found in caſual detached maſſes on the ſurface of the earth, in their cellular texture, and in their chemical compoſition, whence it is probable that they have originated from ſimilar cauſes, and the hypotheſis of their having fallen from the atmoſphere appears to be ſupported by ſtrong analogy as well as vulgar tradition; but for further particulars on this curious ſubject we refer the reader to the article STONES *meteoric*.

Native iron has alſo been found imbedded in brown ironſtone, ſpathoſe ironſtone, and heavy ſpar, at Kamſdorf in Saxony, and is ſaid to have occurred ſtalactitical with brown ironſtone and quartz, forming a vein in the mountain of Oulle near Grenoble.

It is remarkable that the native iron in detached maſſes, or as Klaproth calls it, the meteoric iron, is in fact an alloy of this metal with nickel, and to this admixture it is no doubt greatly indebted for the long reſiſtance that it makes to the combined action of air and moiſture. Common hammered iron is of all metallic ſubſtances the moſt eaſily corroded by ruſt, yet the native iron oxydates with great difficulty.

But although chemiſts are agreed reſpecting the nature of the ingredients of meteoric iron, they vary remarkably in their accounts of the proportions. This difference is partly to be attributed to a real variation in the proportions, but principally to the different methods that have been had recourſe to in eſtimating the amount of the nickel.

Mr. Howard[e] endeavoured to aſcertain the quantity of nickel by the following proceſs. He firſt diſſolved ſome pure bar iron in nitric acid, and precipitated the oxyd by cauſtic ammonia, and from the reſult of ſeveral experiments found that 100 parts of iron thus treated, afforded 145 of oxyd; but oxyd of nickel is not precipitable by ammonia, therefore in proportion to the nickel contained in the alloy will the oxyd procured fall ſhort of the eſtimated amount which pure iron would have afforded. Thus 100 grains of the Siberian iron yielded 127 of oxyd of iron, hence the proportion of nickel which it contains, is 12.5 per cent. (not 17 per cent. as Mr. H. has inadvertently ſtated) for

: 145 oxyd : 100 iron :: 127 oxyd : 87.5 iron; therefore the *Siberian* iron conſiſts of

87.5 Iron
12.5 Nickel

100.0

Again in like manner the *S. American* iron yielded 80 grains of oxyd from 62 of the metal; hence it contained, not as Mr. H. ſtates, 10 per cent. but 11 per cent. of nickel, for : 145 : 100 : : 80 : 55.1, hence the 62 grains conſiſted of 55.1 iron, and 6.9 nickel; therefore 100 parts of this contains

88.9 Iron
11.1 Nickel

100.0

So the *Bohemian* iron gave 30 grains of oxyd from 25 of the metal, and therefore conſiſted of

82.4 Iron
17.6 Nickel

100.0

Laſtly the *Senegal* iron yielded 199 grains of oxyd from 145 of metal, and therefore contained not between 5 and 6 per cent. as Mr. H. ſtates, but

95.2 Iron
4.8 Nickel

100.0

The South American iron has been analyſed alſo by M. Prouſt,[f] but in a different way from that followed by Mr. Howard. M. Prouſt found that 100 grains of iron wire yielded with dilute ſulphuric acid, 200 cubic inches of hydrogen gas; but 100 grains of native iron gave only 176 inches, therefore : 200 : 100 : : 176 : 88, hence the amount per cent. of the two metals is

88 Iron
12 Nickel

100

which agrees very ſatisfactorily with the proportions indicated by Mr. Howard.

But Klaproth, according to Jameſon,[g] has analyſed ſome native irons with reſults, if they are correctly reported, widely differing from thoſe which we have juſt quoted. According to this able chemiſt the meteoric iron of Bohemia and Siberia conſiſts of

[e] Phil. Tranſ. xcii. p 191. [f] Ann. de Chem. xxxv. p. 47. [g] Mineralog. ii. p. 250.

B.		S.	
96.5	—	98.5	Iron
3.5	—	1.5	Nickel
100	—	100	

The proper native iron of Kamſdorf in Saxony, according to the ſame authority, is compoſed of

92.5	Iron
6.0	Lead
1.5	Copper
100.0	

Sp. 2. Unmagnetical Iron Pyrites.

Of this there are the five following ſubſpecies.

1. *Subſp.* Common Pyrites. *Gemeiner Schwefelkies.* Wern. *Pyrite martiale commune.* Broch.

Its colour is perfect braſs-yellow, ſometimes by tarniſhing it is ſuperficially reddiſh or browniſh.

It occurs maſſive, diſſeminated, inveſting, and cryſtallized. Its primitive cryſtalline form is the cube, which paſſes into the following varieties:

1. The cube, with convex faces.

2. The cube with ſolid angles replaced by triangular facets, ſo as to be intermediate between the cube and octohedron.

3. The cube with its edges replaced by narrow planes inclined more towards one than the other of the adjacent faces.

4. The cube with the three plane angles that form each of the ſolid angles, replaced by ſecondary angles of more than 90°.

5. The octohedron either perfect or with all its ſolid angles replaced by planes.

6. The dodecahedron with pentagonal faces.

7. The ſame, with ſix oppoſite and parallel edges replaced by narrow planes.

8. The dodecahedron with eight of its angles replaced by planes, forming the paſſage into the icoſahedron.

9. The perfect icoſahedron. This variety is extremely rare.

10. The ſame, with four edges replaced by narrow planes.

11. The triacontahedron, formed of thirty rhombic faces.

The cryſtals are moſtly ſmall, but the cubes are often middle-ſized; they are ſometimes ſingle, but oftener variouſly aggregated. The ſurface of the cryſtals is generally ſmooth, but the cubes ſometimes occur ſtriated in three directions: their luſtre varies from ſpecular to gliſtening. Internally it is feebly-ſhining, with a metallic luſtre. Its fracture is coarſe or fine-grained uneven. Its fragments are indeterminately angular. It does not yield to the knife; and gives red ſparks with ſteel: it is opake, brittle, not very frangible, and by percuſſion affords a ſulphureous odour. Sp. gr. of the cryſtallized, 4.78 : 4.83.

When expoſed to the blowpipe on charcoal, it emits a ſtrong ſulphureous odour, and burns with a bluiſh flame. It then becomes a browniſh globule, attractable by the magnet, and by a further continuance of the heat paſſes into a blackiſh ſlag.

According to the experiments of Mr. Hatchett,[h] the pyrites with ſmooth cubes conſiſts of

Sulphur	52.70
Iron -	47.30
	100.0

Pyrites with ſtriated cubes contains

Sulphur	52.5
Iron -	47.5
	100.0

and dodecahedral pyrites contains

Sulphur	52.15
Iron -	47.85
	100.00

The ſtriated cubes and dodecahedrons ſometimes contain gold, and hence are named auriferous pyrites.

Common pyrites occurs in almoſt every mineral formation, and almoſt every ſpecies of rock. It abounds in granite, and particularly in primitive and tranſition argillaceous ſchiſtus.

It is never wrought as an ore of iron, but is largely employed in the manufacture of green vitriol, and ſulphur is often procured from it by ſublimation, while the reſidual red oxyd is valuable as a coarſe kind of paint.

2. *Subſp.* Radiated Pyrites. *Strahlkies.* Germ. *Pyrite rayonnée.* Broch.

Its colour is braſs-yellow, but paler than common pyrites; its ſurface is generally tarniſhed. It occurs in maſs, but moſt uſually in particular forms, ſuch as kidney-ſhaped, tuberous, globular, botryoidal, ſcaly, ſtalactitic, &c. Alſo in minute cryſtals between the cube and octohedron. When the cryſtals are very much flattened and united in diverging groups, they form the cock's-comb pyrites. The ſurface of the cryſtals is

[h] Phil. Tranſ. xciv. p. 315.

either ſmooth or druſy, and therefore their external luſtre is ſubject to correſponding variations. The fracture is for the moſt part divergingly radiated in ſtars or bundles, with ſhort ſtrait fibres. It ſometimes paſſes into parallel-fibrous, and even into compact. Its fragments are wedge-ſhaped. It occurs in coarſe and large granular diſtinct concretions, alſo in thin curved lamellar, and in thin columnar diſtinct concretions. It is hard, brittle, and very eaſily frangible. Sp. gr. 4.69 to 4.77.

It is compoſed according to Hatchett of

Sulphur	53.6 —	54.34
Iron -	46.4 —	45.66
	100.	100.

It is rarer than common pyrites, and occurs principally in ſmall maſſes, and in veins with ores of lead or ſilver. In Britain it occurs in Cornwall, the Iſle of Sheppy, and Derbyſhire. It is remarkably ſubject to decompoſition on expoſure to the air and moiſture, and hence is much ſought after by the manufacturers of green vitriol.

3. *Subſ.* Capillary pyrites. *Haarkies.* Wern. *Pyrite Capillaire.* Broch.

Its colour is bronze yellow, paſſing into ſteel-grey. It occurs in delicate capillary cryſtals aggregated into divergent bundles or promiſcuouſly. In other particulars it agrees with the preceding, of which it is little elſe than a variety.

It is the leaſt frequently met with of any of the kinds of pyrites. It occurs in veins with lead and ſilver ores, accompanied by quartz, calcareous and fluor ſpars, in Saxony and the Hartz.

4. *Subſp.* Cellular pyrites. *Zell-kies,* Wern.

Its colour is bronze yellow inclining to greeniſh and ſteel-grey. It becomes of a grey colour by tarniſhing. It occurs cellular: its fracture is even and flat conchoidal paſſing into fine-grained uneven. In other reſpects it reſembles common pyrites, into which it occaſionally paſſes. It is the leaſt ſubject to decompoſition of the whole ſpecies. It occurs in metallic veins in Saxony.

5. *Subſp.* Liver pyrites. *Leberkies,* Wern. *Pyrite hepatique,* Broch.

Its colour is intermediate between pale braſs-yellow and ſteel-grey; its external ſurface is uſually browniſh or irideſcent. It occurs in maſs, diſſeminated, globular, tuberous, reniform, ſtalactitic and cellular; alſo cryſtallized in ſix-ſided priſms or pyramids. Internally it is uſually glimmering, with a metallic luſtre. Its fracture is even, paſſing into fine granular or flat conchoidal. It occurs in diſtinct concretions. It is met with only in metallic veins and is very ſubject to decompoſition.

Sp. 3. Magnetical Pyrites. *Magnetkies,* Wern. *Pyrite magnetique,* Broch.

Its colour is intermediate between braſs-yellow and copper-red, and ſometimes inclines to tombac brown: by expoſure to the air it acquires a browniſh tarniſh. It occurs only in maſs and diſſeminated. Internally it is ſhining or gliſtening, with a metallic luſtre. Its fracture is fine or coarſe grained uneven, ſometimes paſſing into imperfect conchoidal. It breaks into indeterminate blunt edged fragments. It affords a few occaſional ſparks with ſteel; is brittle and eaſily frangible. Sp. gr. 4.518.

It is eſpecially diſtinguiſhable from the preceding ſpecies in being attracted by the magnet and giving out ſulphuretted hydrogen by digeſtion in muriatic acid. Its component parts, according to Mr. Hatchett, are

Sulphur - -	36.5
Iron - - -	63.5
	100.

It is ſaid to be found only in beds in primitive mountains, in gneiſs, micaceous ſchiſtus, primitive greenſtone and limeſtone, where it occurs with common martial pyrites, copper pyrites, arſenical pyrites, galena, blende, magnetic iron-ſtone, garnet, hornblende, and actynolite. It is met with in Bohemia, Bavaria, and Sileſia, alſo in Norway, and has recently been found by Mr. Greville near the baſe of Moel Elion in Caernarvonſhire, where it forms a thick vein or more properly a bed, as Jameſon conjectures. Beſides the above localities it occurs diſſeminated in tranſition greenſtone a little to the ſouth of Pont Aberglaſlyn in Caernarvonſhire; and forming a large bed with black calcareous ſpar in tranſition ſlate, not far from Trefriew in the vale of Conway, in the ſame county. At this laſt place it is procured in conſiderable quantity for the ſulphur which it yields by ſublimation and the red ochre which remains after the ſeparation of the ſulphur.[1]

Sp. 4. Magnetical Iron Stone.

Of this there are the two following ſubſpecies.

1. *Subſp.* Common Magnetic Iron ſtone. *Gemeiner Magneteiſenſtein,* Wern. *Fer magnetique commun,* Broch.

[1] Own Obſervations.

Its colour is iron-black, often ſuperficially tarniſhed. It occurs maſſive, diſſeminated and cryſtallized. The forms of its cryſtals are,

1. The octohedron.
2. The garnet dodecahedron.
3. A rectangular four-ſided priſm, terminated by four-ſided pyramids.

The cryſtals are uſually either imbedded or accumulated on each other, and are ſmall and middle-ſized. The internal luſtre varies between bright-ſhining and glimmering, and is metallic. Its fracture is generally coarſe or fine granular, uneven; ſometimes alſo ſmall conchoidal and imperfectly lamellar. It ſometimes, though rarely, occurs in coarſely granular and very looſe diſtinct concretions. It gives a browniſh black ſtreak and is conſiderably hard. The cryſtals are very difficultly frangible, but the granular varieties are more eaſily broken. Sp. gr. 4.2 to 4.9.

It is not only attractable by the magnet, but itſelf poſſeſſes polarity, hence it takes up iron filings. Before the blowpipe it becomes brown and tinges glaſs of borax of a dark green colour. It has not been regularly analyzed, but is ſuppoſed to be nearly a pure oxyd of iron. When ſmelted in the large way it is ſaid to yield from 80 to 90 per cent. of metal, but this is manifeſtly impoſſible; a more probable eſtimate is from 60 to 70 per cent. It occurs moſt frequently in primitive mountains and chiefly in gneiſs, micaceous ſchiſtus, chlorite ſlate, and primitive limeſtone: alſo in ſerpentine, and in the floetz-trap formation. When in maſs it forms beds and ſometimes conſiderable rock-maſſes. It is uſually accompanied by horn-blende, granular limeſtone, and garnet; alſo, though more rarely, by amianth, actynolite, fluorſpar, coccolite, ſahlite, augite, all the varieties of pyrites, blende, tinſtone and galena.

The Mountain Taberg in Swediſh Lapland, and Pumachanche in Chili, are ſaid to conſiſt almoſt entirely of this mineral. It exiſts in great abundance and purity in Roſlagia in Sweden, where it is manufactured into the beſt bar iron, ſo much ſought after by the Engliſh manufacturers of ſteel. It alſo occurs in ſufficient plenty to be ſmelted in the iſlands of Corſica and Elba; Arendahl in Norway; in Saxony, Bohemia, Sileſia, and the Hartz in Germany; in many places among the Uralian mountains in Ruſſia; and in Siam in the Eaſt Indies.

When pure it affords the beſt bar iron, but only middling caſt iron: it is eaſily fuſible and requires but little flux.

2. *Subſp.* Magnetic iron ſand. *Eiſenſand*, Wern. *Fer magnetique ſabloneux*, Broch.

Its colour is deep iron black. It occurs in angular and roundiſh grains from the ſmalleſt dimenſions to the magnitude of a hazel-nut; alſo in octohedral cryſtals. Both the grains and cryſtals are externally ſomewhat rough and glimmering. Internally it exhibits a bright-ſhining metallic luſtre. Its fracture is perfectly conchoidal and rarely imperfectly foliated. Its fragments are indeterminate and ſharp-edged. It gives a greyiſh-black powder. It is moderately hard, brittle and eaſily frangible. Sp. gr. 4.6.

It is powerfully attracted by the magnet, but is ſcarcely at all acted on by the muriatic or nitric acids.

It ſeems to belong almoſt entirely to the floetz-trap formation, and is found imbedded in baſalt and wakke or looſe in the beds of rivers. It does not often occur in ſufficient abundance to be ſmelted, yet it is employed for this purpoſe in the Tyrol, near Naples, and in Virginia, and produces about 60 per cent. of excellent bar iron.

Sp. 5. Specular Iron Ore. *Eiſenglanz*, Wern.

Of this there are the two following ſubſpecies.

Subſ. 1. Common Specular Iron ore. *Gemeiner Eiſenglanz*, Wern. *Fer ſpeculaire commun*, Broch.

Its uſual colour is deep ſteel-grey, paſſing ſometimes in the cryſtallized varieties to iron black, and in the maſſive varieties to browniſh red. It is often tarniſhed externally, and then preſents the blue and yellow tints of tempered ſteel. It occurs in maſs, diſſeminated and cryſtallized. The forms of its cryſtals are,

1. A compreſſed hexahedron compoſed of two three-ſided pyramids ſet baſe to baſe with the angles of the one correſponding with the ſides of the other.
2. The ſame, with the angles at the baſe truncated.
3. The cube with its edges replaced by narrow planes.
4. A double ſix-ſided priſm deeply truncated.
5. A ſix-ſided table: ſometimes ſeveral of theſe are grouped together ſo as to form cells.
6. A low equiangular ſix-ſided priſm.
7. Lenticular.

The planes of the cryſtals are ſometimes ſmooth and ſometimes ſtriated, but in the cube are always ſtriated diagonally. Its external luſtre is generally bright-ſhining metallic. Its fracture is compact or foliated; the compact is

granular uneven paſſing into imperfect and ſmall conchoidal; the foliated has a fourfold rectangular cleavage. Its fragments are octohedral or pyramidal, ſometimes indeterminately angular. It ſometimes though rarely preſents granular diſtinct concretions, alſo imperfectly wedge-ſhaped and more frequently thick lamellar, either ſtrait or curved, diſtinct concretions. The colour of its ſtreak is cherry-red. It is hard, brittle, not very eaſily frangible. Sp. gr. 4.7. to 5.2.

When pulverized it is ſlightly magnetic. It is infuſible *per ſe*, before the blowpipe; with borax it gives a dirty yellow flag. According to Kirwan it conſiſts of iron and oxygen in the proportion of from 60 to 80 of the former and from 20 to 30 of the latter.

It occurs in beds and veins in primitive and tranſition mountains, and is generally accompanied by magnetic iron-ſtone and compact red iron-ſtone, iron pyrites and quartz. The greater part of the iron ore of Elba is of this ſpecies; it alſo abounds in Sweden and Norway, in Bohemia, Saxony, Sileſia, Switzerland, France, Ruſſia, and Siberia. It affords an excellent malleable iron, but ſomewhat hard, and alſo a good but not the very beſt caſt iron.

2. *Subſp.* Micaceous iron ore. *Eivenglimmer*, Wern. *Fer micacée*, Broch.

Its colour is iron-black paſſing into ſteel-grey; and the thin plates of which it conſiſts when held between the eye and the light appear blood-red. It occurs maſſive, diſſeminated, or ſuperficial, or cryſtallized in thin hexahedral tables, which ſometimes interſect one another ſo as to form cells. The ſurface of the cryſtals is ſmooth and almoſt ſpecular. Internally it is more or leſs ſhining, with a metallic luſtre. Its fracture is perfectly foliated; the lamellæ are curved and diviſible only in one direction. Its fragments are either indeterminate or in the form of plates. When in maſs it occurs in thin and curved lamellar or granular diſtinct concretions. The thin plates are ſometimes faintly tranſlucent. The colour of its ſtreak is cherry red. It is moderately hard, but becomes ſoft in proportion as it paſſes into the red ſcaly iron ore; it is brittle and eaſily frangible. Sp. gr. 4.5 to 6.0.

It occurs only in primitive mountains, but chiefly abounds in the moſt recent of theſe. It lies in beds and veins accompanied by red and brown iron-ſtone and iron pyrites.

It affords on analyſis upwards of 70 *per cent.* of iron. In the great way it is found to melt more eaſily than the preceding ſubſpecies, provided a ſufficient quantity of limeſtone is added to it by way of flux. The iron that it affords is ſometimes cold-ſhort but is well fitted for caſt ware.

It is met with in Norway, Sweden, various parts of Germany, Dauphiné in France, Piedmont and the iſland of Elba in Italy, the foreſt of Dartmoor in Devonſhire, near Dunkeld in Perthſhire, and in Mainland, one of the Shetland iſlands.

Sp. 6. Red Ironstone. *Rotheiſenſtein*, Wern. Of this there are four ſubſpecies.

1. *Subſp.* Red ſcaly iron ore. *Rother Eiſenrahm*, Wern. *Eiſenrahm rouge*, Broch.

Its proper colour is cherry red, but it alſo paſſes into blood-red, browniſh-red, ſteel-grey and iron-black. It occurs ſometimes in maſs, but more frequently as a ſuperficial covering to other ores of iron. It is gliſtening, with a ſemi-metallic luſtre. It is compoſed of friable ſcaly particles more or leſs cohering together. It ſtains the fingers, is unctuous to the touch, and moderately heavy.

When expoſed to the blowpipe without addition it blackens but does not melt. It communicates to glaſs of borax an olive green colour.

Its component parts, according to Mr. W. Henry[k], are

Iron	- -	66.
Oxygen	-	28.5
Silex	- -	4.25
Alumine	-	1.25
		100.00

It occurs uſually in veins in primitive mountains, alſo in tranſition mountains. It is commonly accompanied by the other ſubſpecies of red ironſtone and ſpathoſe iron. It paſſes into micaceous iron ore.

It is found at Ulverſtone and other places in the North of Lancaſhire. At Sahl in the Dutchy of Henneberg it is ſmelted and produces very good iron.

2. *Subſp.* Red Ochre. *Ockricker Rotheiſenſtein*, Wern. *Ochre de Fer rouge*, Broch.

Its colour is blood-red paſſing into browniſh red. It is found in maſs, diſſeminated and ſuperficial. It has little or no luſtre. Its fracture is earthy. It ſtains the fingers; is uſually friable and very tender, but in ſome varieties paſſes into ſolid: to the touch it is ſmooth and ſomewhat meagre. Sp. gr. 2.95.

It is found accompanying the other ſubſpecies

[k] Nicholſon's Journ. 4to, vol. iii. p. 454.

of red iron-ſtone, but rarely in any conſiderable quantity. It is ſmelted in the Irrgange near Platte in Bohemia, is very fuſible, and affords excellent malleable iron.

3. *Subſp.* Compact red Iron-ſtone. *Dichter Rotheiſenſtein*, Wern. *Mine de Fer rouge compacte*, Broch.

Its colour is intermediate between brownifh red and dark ſteel-grey, it paſſes ſometimes to blood-red. It occurs in maſs or diſſeminated, or in particular ſhapes, ſuch as globular reniform, ſpecular, cellular, in pſeudomorphous pyramidal cryſtals or rarely in real cubic cryſtals either ſolitary or in groups. The ſurface of the true cryſtals is ſmooth, of the others rough. The external luſtre is ſubject to ſeveral variations; internally it is rarely more than glimmering, ſemi-metallic. Its fracture is commonly even, whence it occaſionally paſſes into coarſe grained uneven and large conchoidal: ſometimes alſo it is found ſlaty. Its fragments are indeterminate blunt-edged. It exhibits rarely teſtaceous or priſmatic diſtinct concretions. It is commonly of moderate hardneſs and eaſily frangible. It gives a blood-red ſtreak and is apt to ſtain the fingers. Sp. gr. 3.42 to 3.76.

It acquires a dark tinge before the blowpipe but is infuſible either by itſelf or with borax, to which however it gives an olive-green colour. Its conſtituent parts, according to Lampadius, are

Oxyd of iron - -	65.4
Silex - - - - -	20.7
Alumine - - - -	9.3
Oxyd of manganeſe	2.7
	98.1

It occurs in beds and veins uſually with red hæmatite and red ochre, alſo with quartz, hornſtone and red jaſper. It is met with in various parts of Germany (the cryſtallized varieties come from Oberhals in Bohemia) in Norway, Siberia and in conſiderable quantities in Lancaſhire. It affords good caſt iron, and pretty malleable though ſomewhat ſoft bar iron.

4. *Subſp.* Red Hæmatite. *Rother Glaſkopf*, Wern. *Hématite rouge*, Broch.

Its colour is intermediate between browniſh red and ſteel-grey, ſometimes it paſſes into blood-red and bluiſh-grey. It occurs in maſs, alſo of particular ſhapes, ſuch as reniform, botryoidal, ſtalactitical and globular. Its external luſtre is caſual; internally, it is uſually gliſtening, with a ſemi-metallic luſtre. Its fracture is ſtrait fibrous either delicate or coarſe; parallel, radiating or in bundles. Its fragments are wedgeſhaped, ſometimes in the coarſe fibrous variety, ſplintery. It occurs almoſt always in diſtinct concretions either large or ſmall granular or curved lamellar. It gives a blood-red ſtreak; is hard, brittle, and generally ſtains the fingers. Sp. gr. 4.84 to 5.0.

It has not yet been analyſed with any accuracy, but from the reſults in the large way it contains about 60 *per cent.* of iron, and is the richeſt of the whole ſpecies. It occurs in the ſame ſituations with the preceding ſubſpecies in veins, beds and rock maſſes in primitive tranſition and floetz mountains. It affords excellent iron both caſt and malleable: moſt of the plate-iron and iron wire of England is made from it. When ground to a fine powder it is largely employed as a poliſhing material by moſt workers in metal.

It is particular abundant in Lancaſhire, in the Foreſt of Dean in Glouceſterſhire, in Devonſhire and in Saxony, but is ſcarcely at all to be met with in Norway, Sweden, Poland, Hungary and Ruſſia.

Sp. 7. Brown Ironstone. *Braun Eiſenſtein*, Wern.

This like the former is to be divided into four ſubſpecies.

1. *Subſp.* Brown ſcaly iron ore. *Brauner Eiſenrahm*, Wern. *Eiſenrahm brun*, Broch.

Its colour is intermediate between ſteel-grey and clove-brown. It occurs ſeldom in maſs, diſſeminated or globular, but more frequently ſuperficial and frothy, ſometimes alſo irregularly dendritical. It has a conſiderable metallic luſtre. Its fracture is ſmall lamellar paſſing into compact. It is very ſoft and almoſt friable; ſtains the fingers, is ſomewhat unctuous to the touch; is light ſo as ſometimes to float on water.

It blackens before the blowpipe but does not melt, it tinges glaſs of borax of a yellowiſh-green colour. It has not been analyſed.

It occurs lining cavities in brown hæmatite.

2. *Subſp.* Brown Iron ochre. *Ockrieker Brauneiſenſtein*, Wern. *Ocre de fer brune*, Broch.

Its colour is light yellowiſh brown, inclining to ochre-yellow and clove-brown. It occurs in maſs and diſſeminated. It is deſtitute of luſtre; has an earthy fracture; its fragments are indeterminate blunt edged. It is tender, paſſing into friable; ſoils the fingers, and is heavy.

It has not been analyſed. It becomes black by ignition, whence it is diſtinguiſhed from yellow earth which burns red. It accompanies brown hæmatite.

3. *Subſp.* Compact brown Ironſtone. *Dichter*

Brauneiſenſtein, Wern. *Mine de fer brune compacte*, Broch.

Its colour is clove-brown. It occurs maſſive and diſſeminated, alſo of particular ſhapes, ſuch as cylindrical, ſtalactitic, reniform, cellular, with pyramidal impreſſions and rarely in pſeudomorphous cubes, rhombs, and lenſes. It alſo forms the ſubſtance of ſeveral petrefactions, eſpecially of madreporites, corallites and fungites. Internally it is dull or faintly glimmering. Its fracture is uſually even, ſometimes large and flat conchoidal, alſo fine grained uneven, and earthy. Its fragments are indeterminate blunt edged. Its ſtreak is yellowiſh-brown paſſing into ochre-yellow. It is moderately hard, and eaſily frangible. Sp. gr. 3.5 to 3.75.

Before the blowpipe it becomes black and magnetic. It accompanies brown hæmatite.

4. *Subſp.* Brown Hæmatite. *Brauner Glaskopf*, Wern. *Hematite brune*, Broch.

The colour of the recent fracture is clove brown paſſing into ſteel-grey, blackiſh brown and browniſh-black, or rarely into yellowiſh brown and ochre yellow. The external ſurface tarniſhes to black, bluiſh black, tombac brown, bronze and gold-yellow: it alſo often preſents bright iridiſcent metallic colours. It occurs ſometimes in maſs, but more commonly ſtalactitic, coralliform, botryoidal, reniform, tuberous, cylindric, cellular, dendritic, and in pſeudomorphous ſix-ſided pyramids. Its ſurface is ſmooth or granular, rarely druſy, and is ſhining. Internally it is only gliſtening with a luſtre between pearly and reſinous. The fracture of the clove-brown varieties is long and delicately fibrous; of thoſe that incline to blue, ſhort and coarſe fibrous; of the black, very delicately fibrous paſſing into conchoidal; of the blackiſh brown, radiated; the fibres are generally more or leſs diverging. The fragments are ſplintery or wedgeſhaped, ſometimes indeterminately angular. It occurs in lamellar and granular diſtinct concretions, ſometimes each concretion is granular externally and lamellar in its croſs-fracture. It is commonly opake; the browniſh black is ſlightly tranſlucent on the edges. Its ſtreak is yellowiſh-brown; it is moderately hard, brittle, and eaſily frangible. Sp. gr. 3.95.

It blackens before the blowpipe and gives an olive-green colour to borax. It has not been analyſed; but in the ſmelting furnace affords from 40 to 60 *per cent.* of iron.

Brown ironſtone occurs in the newer of the primitive mountains, but more frequently in tranſition and floetz mountains: it is found in veins, beds and rock maſſes, and is accompanied by black ironſtone, ſpathoſe ironſtone, brown ſpar, calcareous and heavy ſpars. It paſſes on one hand into red ironſtone and on the other into ſpathoſe ironſtone.

It melts eaſily and for the moſt part without a flux; when one is required argillaceous ſchiſtus is generally made uſe of. The caſt iron which it affords is not equal to that from red ironſtone; but the bar iron is both very malleable and hard, probably from the manganeſe which it contains: hence it yields excellent ſteel. It occurs in great abundance in Saxony, Bohemia and other parts of Germany, alſo in Tyrol, Carinthia, Stiria, Piedmont, and the South of France. It is ſcarcely at all to be met with in Norway, Sweden or Ruſſia; it is found in Cornwall, and occaſionally in other parts of Britain, but not in ſufficient abundance to be wrought.

Sp. 8. Spathose Ironstone. *Spatheiſenſtein*, Wern. *Fer ſpathique*, Broch.

Its colour is greyiſh yellow, paſſing into Iſabella yellow and greeniſh-grey; it is alſo found hair and clove-brown and browniſh-black. It occurs in maſs, diſſeminated, with pyramidal impreſſions and very often cryſtallized. The forms of its cryſtals are the following.

1. A perfect rhomboid with plane or convex faces.

2. The ſame, with the obtuſe angles deeply truncated.

3. The lens, either regular or turned up at the edges in form of a ſaddle.

4. An octohedron with plane or convex faces and ſometimes truncated on the angles.

The cryſtals are uſually middleſized or ſmall. The ſurface of the octohedron is ſmooth and ſpecular; of the other cryſtals druſy and rough. Internally it is more or leſs ſhining with a luſtre between pearly and vitreous. Its fracture is foliated, with ſtraight or curved lamellæ: it is diviſible in three directions croſſing each other obliquely. Its fragments are rhomboidal. It generally preſents granular diſtinct concretions. The light coloured varieties are tranſlucent either entirely or at leaſt at the edges, thoſe of a deep colour are opake; the former give a greyiſh-white ſtreak, the latter a yellowiſh-brown one. It is harder than calcareous ſpar, and eaſily frangible. Sp. gr. 3.6 to 3.8.

Before the blowpipe it becomes black and magnetic but does not melt; with borax it forms a ſpungy dirty yellow maſs: it effervesces ſlowly with acids. Specimens from Sweden and Stiria

have been analyſed by Bergman[1] with the following reſults.

	Stirian.	Swediſh.
Oxyd of iron - -	38 =	22
Oxyd of manganeſe	24 —	28
Carbonat of lime -	38 —	50
	100	100

100 parts of the Stirian afforded by fuſion with borax in a lined crucible 42 parts of a ſilvery white regulus.

It occurs in veins in primitive mountains accompanying lead, ſilver, and copper ores. In floetz mountains it forms beds, and is accompanied by brown iron ore, brown ſpar, and calcareous ſpar.

It is found in ſmall quantities in Britain and the North of Europe, and is ſufficiently abundant to be manufactured chiefly in the following places. At Schmalkalden in Heſſe is a bed of the black variety 25 fathoms thick, which has been worked for ſeveral centuries. In Weſtphalia the light coloured is prodigiouſly abundant. At Eiſenerz in Stiria, Hüttenberg in Carinthia, Jauberling in Carniola, and Schwatz in the Tyrol, are large founderies ſupplied by this ore. At Somororſtro in Biſcay is an entire hill compoſed of this ſpecies.

The iron obtained from this ore is particularly valuable, as it may be converted into excellent ſteel immediately from the ſtate of caſt iron: the bar iron formed from it is both hard and tough.

Sp. 9. Black Ironstone. *Schwarz Eiſenſtein*, Wern. *Mine de Fer noire*, Broch.

Of this there are two ſubſpecies.

1. *Subſp.* Compact black ironſtone. *Dichter Schwarzeiſenſtein*, Wern.

Its colour is between bluiſh-black and ſteel-grey. It occurs in maſs, tuberous, reniform, botryoidal, &c. Its internal luſtre is glimmering, ſemimetallic. Its fracture is conchoidal paſſing into fine-grained uneven. Its fragments are indeterminately angular. It forms thin and concentric curved lamellar concretions. It is moderately hard, brittle, and eaſily frangible. Sp. gr. 4.07.

It occurs in primitive and floetz mountains accompanied by brown ironſtone, ſpathoſe ironſtone and quartz. It is a rare mineral and appears to have been found only in Saxony, the Upper Palatinate, Heſſia and ſome other parts of Germany.

It is eaſily fuſible and yields a good iron, but corrodes the ſides of the furnace. It was long confounded with the compact grey manganeſe.

2. *Subſp.* Black Hæmatite. *Schwarzer Glaskopf*, Wern.

This differs from the preceding in the following particulars. Its colour inclines more to a ſteel-grey. Its fracture is very delicately fibrous paſſing into even: the fibres are either curved or ſtrait, bundled or diverging round a centre. The fragments are wedge-ſhaped. It occurs in coarſe-grained diſtinct concretions. It has hitherto been found only at Schmalkalden in Heſſia.

Sp. 10. Argillaceous Ironstone. *Thoneiſenſtein*, Wern.

In this are comprehended the ſeven following ſubſpecies.

1. *Subſp.* Reddle or Red chalk. *Roethel*, Wern. *Crayon rouge*, Broch.

Its colour is light-browniſh red paſſing into cherry red. It occurs only in maſs. Its principal fracture is fine-ſlaty and glimmering; its croſs fracture is fine earthy and dull. Its fragments are commonly tabular, alſo ſplintery or indeterminate. The colour of its ſtreak is ſimilar to that of the mineral in maſs, but is ſomewhat lighter and more ſhining. It ſoils the fingers, and may be uſed to write with. It may readily be cut with a knife, is eaſily frangible, adheres ſtrongly to the tongue, is ſoft but meagre to the feel. Sp. gr. 3.1 to 3.9.

When expoſed to a red heat it decrepitates and becomes black: at a high heat it melts into a greeniſh-grey frothy enamel.

It occurs generally in the newer argillite, forming entire beds or large imbedded maſſes.

In Sileſia it is ſaid to be found in compact limeſtone.

It is found in various parts of Germany, but is principally wrought at Thalitter in Heſſia. It is never ſmelted for the iron that it contains, but is largely uſed for drawing and marking: the coarſer varieties are employed by the carpenter and the finer by the painter. What are vulgarly called *Red-lead pencils* are compoſed of thin ſlips of the finer kinds of reddle incloſed in a wooden caſe.

2. *Subſp.* Columnar argillaceous Ironſtone. *Stanglicher Thoneiſenſtein*, Wern. *Fer argilleux ſcapiforme*, Broch.

Its colour varies between liver-brown and cherry-red. It occurs in maſs and in globular and angular pieces. It is dull, and has a fine earthy fracture. It forms columnar diſtinct concretions either thick or thin, ſtrait or curved,

[1] Eſſ. ii. p. 230.

parallel or diverging, ſometimes they are articulated. The ſurface of the concretions is rough and dull. Its ſtreak is blood-red or yellowiſh brown. It is ſoft, brittle, very eaſily frangible; adheres to the tongue, is meagre and ſomewhat rough to the touch, and moderately heavy.

It blackens before the blowpipe, effervesces with borax, and communicates to it an olive-green colour.

It is found in beds of ſhale, and ſeems in many caſes to be a pſeudo-volcanic product, being accompanied by porcellanite and burnt clay.

It occurs in the Upper Palatinate, in Bohemia and other parts of Germany, and has been found by Jameſon in the Iſle of Arran. It is by no means a common mineral, and is ſcarcely ever employed as an ore of iron.

3. *Subſp.* Lenticular argillaceous Ironſtone. *Linzenformiger Thoneiſenſtein*, Wer. *Fer argilleux lenticulaire*, Broch.

Its colour is reddiſh or yellowiſh-brown, browniſh-red, and greyiſh-black. It occurs in maſs. Its luſtre is gliſtening, ſtrongly ſemimetallic. Its fracture is uneven paſſing into thin flaty. Its fragments are indeterminately angular blunt-edged. It occurs in ſmall and round granular or in compreſſed lenticular diſtinct concretions; theſe laſt are conſidered by many authors as actual petrefactions. It gives a ſlightly-ſhining ſtreak, not materially differing in colour from the entire mineral. It is ſoft, brittle and eaſily frangible. The black variety is often magnetical.

According to Lampadius it conſiſts of

Oxyd of iron - - -	64.
Alumine - - - - -	23.
Silex - - - - -	7.5
Water - - - - -	5.
	99.5

The red variety, which is commonly in lenticular diſtinct concretions, occurs in rock maſſes in tranſition mountains. The brown and black varieties, which are in granular diſtinct concretions occur in beds between the variegated ſandſtone and the moſt recent ſhell-limeſtone.

The red and brown varieties abound in various part of the European continent, the black has hitherto been only found in the canton of Berne.

The red affords excellent caſt iron, the brown affords both bar and caſt iron of a good quality; the black gives a large quantity of iron, but of a bad quality, and is difficult of reduction.

4. *Subſp.* Jaſpery argillaceous Ironſtone. *Jaſpiſartiger Thoneiſenſtein*, Wern.

Its colour is browniſh-red. It occurs in maſs; it is internally feebly glimmering. Its fracture is flat-conchoidal paſſing into even. Its fragments approach more or leſs to the cubical form. It is moderately hard, brittle and eaſily frangible. The ſhape of its fragments, and the general reſemblance of its external appearance to common jaſper, diſtinguiſh it from the other ſubſpecies.

It occurs between Vienna and Hungary in a large bed.

5. *Subſp.* Common argillaceous Ironſtone. *Gemeiner Thoneiſenſtein*, Wern. *Fer argilleux commune*, Broch.

Its uſual colour is yellowiſh or bluiſh-grey, or ſteel-grey; frequently alſo yellowiſh or reddiſh brown; theſe colours alter much by expoſure to the air and become in general deeper, nor does this change take place at the ſurface alone but penetrates frequently through the whole maſs. It occurs in maſs or diſſeminated, ſometimes alſo cellular, and containing impreſſions of ſhells and vegetables. Internally it is dull. Its fracture is commonly earthy, ſometimes fine-grained uneven, or flat-conchoidal, or flaty. Its fragments are indeterminate. It has for the moſt part only a very moderate degree of hardneſs. It is brittle; eaſily frangible; adheres a little to the tongue; is meagre to the feel. Sp. gr. 2.93 to 3.47.

It blackens before the blowpipe, and gives with borax a blackiſh-green glaſs.

It appears to conſiſt eſſentially of oxyd of iron, alumine and a little ſilex; there is alſo a ſmall variable proportion of pyrites diſperſed through it. The amount of iron which it yields in the large way varies between 30 and 40 *per cent.*

It occurs in beds in floetz mountains; eſpecially in the independent coal-formation and the neweſt floetz-trap. The large eſtabliſhments at Carron in Scotland, Coalbrookdale in England, Merthyr Tydvil in South Wales, &c. are principally ſupplied by this ore.

It bears a conſiderable reſemblance to compact limeſtone and indurated clay, but is diſtinguiſhed from them by its ſuperior ſpecific gravity and perfect opacity.

6. *Subſp.* Nodular Ironſtone. *Lapis Etites. Eiſenniere*, Wern. *Fer reniforme*, Broch.

Its colour is yellowiſh-brown of various degrees of intenſity: internally the colour is lighter and it often incloſes an ochre-yellow kernel. It occurs in roundiſh maſſes from the

size of a walnut to that of a man's head. Its fracture is even towards the surface and fine-earthy towards the centre. The external layers are semi-metallic and glimmering, but towards the centre it is dull. The fragments are indeterminate. It occurs in lamellar concentric distinct concretions, often inclosing a loose kernel. The exterior layers are soft, the internal are very soft, almost friable. It is brittle, easily frangible, adheres to the tongue. Sp. gr. 2.57.

It occurs imbedded in ferruginous clay in the most recent floetz mountains, also in the floetz-trap and coal formations. It yields an iron of fine quality and is largely manufactured both in England and Scotland, especially at the places mentioned under the last subspecies.

7. *Subsp.* Pea shaped, or Pisiform, Ironstone. *Bohnerz*, Wern. *Fer Pisiforme*, Broch.

Its external colour is accidental and is yellowish, reddish or greyish: internally it is yellowish-brown passing into blackish brown. It occurs in small round grains, sometimes spherical, sometimes slightly compressed. Its surface is rough and dull: internally it is dull at the centre, but acquires gradually a glistening resinous lustre in proportion to the distance from the centre. Its fracture is fine-earthy at the centre, but even towards the surface. It occurs in thin concentric lamellar distinct concretions; gives a yellowish-brown streak, is soft, not very brittle, but easily frangible.

According to an analysis by Vauquelin, it contains

Iron - - -	30
Oxygen - -	18
Alumine - -	31
Silex - - -	15
Water - - -	6
	100

It occurs in cavities in secondary floetz limestone, the grains being concreted together by calcareous stalactite: it also occurs in beds of clay, and in flat beds immediately beneath the surface.

It occurs in various parts of Germany, Switzerland, France, and Dalmatia.

Its produce of metal varies from 30 to 40 *per cent.* it supplies very considerable ironworks at Arau near Berne, and the greater part of the French iron is said by Brochant to be produced from this ore.

Sp. 11. Bog Iron-ore. *Rasen Eisenstein*, Wern. *Mine de Fer de gazon*, Broch.

Of this there are the three following subspecies.

1. *Subsp.* Morass ore. *Morasterz*, Wern. *Mine des Marais*, Broch.

Its colour is yellowish-brown. It occurs sometimes in the state of friable earthy particles, sometimes in mass, or tuberous or carious. It is dull both externally and internally: its fracture is earthy: it stains the fingers, is fine-grained but meagre to the feel; and moderately heavy.

2. *Subsp.* Swamp ore. *Sumpferz*, Wern. *Mines des Lieux bourbeux*, Broch.

Its colour is dark yellowish-brown, passing into dark yellowish-grey. It occurs in amorphous masses, also tubercular and carious. Internally it is dull, but the darker varieties are glimmering. Its fracture is earthy, passing into fine-grained uneven. It gives a clear yellowish-brown streak; is very soft, brittle, and easily frangible. Sp. gr. 2.94.

3. *Subsp.* Meadow ore. *Wiesenerz*, Wern. *Mine des prairies*, Broch.

Its colour is internally between blackish and yellowish-brown; in the clefts it exhibits a bluish-black and steel-grey tinge. It occurs massive, in rounded lumps, perforated, and tuberous. It is internally shining or glistening, with a resinous lustre. Its fracture is minute conchoidal or earthy, or even, or fine-grained uneven. It gives a yellowish-brown streak; is soft, brittle, and easily frangible.

All the preceding subspecies belong to the same formation and appear to be the most recent of any of the ores of iron. They are probably formed by deposition from water which has become charged with iron by means either of carbonic acid or the vegetable acid that is generated in morasses and marshes. The meadow ore is the oldest and the morass ore the newest.

It occurs in Britain and various other parts of the North and East of Europe. It yields from 30 to 36 *per cent.* of iron, well fitted for the finest kinds of cast ware. For wire or plate iron it is not qualified, on account of its being more or less cold-short, which is supposed to arise from a mixture of phosphoric acid. The usual flux employed in smelting it is limestone; it is also often mixed with red or brown ochre or hæmatite, by which the fusion of each is facilitated, and the produce improved both in quantity and quality.

Sp. 12. Blue Martial Earth. *Blaue Eisenerde*, Wern. *Fer terreux bleu*, Broch.

Its colour when recently dug is said to be white, but it afterwards acquires an indigo-blue or smalt-blue, or various degrees of intensity. It occurs in mass, disseminated or investing, but

always in dull pulverulent particles, more or less cohering. It stains the fingers, is meagre to the touch, and moderately heavy.

Before the blowpipe it becomes of a reddish-brown and then melts into a black shining globule, attractable by the magnet. It tinges glass of borax brown, which at length becomes dark yellow. It is readily soluble in acids.

It has been supposed by some to be native Prussian blue, and by others to contain phosphoric acid, but its analysis by Vauquelin discovered nothing except iron, alumine, and lime.

It occurs in nests in beds of clay, and disseminated in bog iron ore, or investing peat.

Sp. 13. Green Martial Earth. *Grune Eisenerde*, Wern. *Fer terreux vert*, Broch.

Its colour is yellowish or olive-green. It occurs generally friable and superficial; rarely in mass, disseminated or carious. Internally it is dull. Its fracture is fine-grained earthy, sometimes uneven. It stains the fingers, is very soft, meagre to the touch, easily frangible, and moderately heavy.

Before the blowpipe it becomes first red, then of a deep brown, but does not melt *per se*. It tinges borax of a greenish-yellow colour. It has been mistaken for bismuth or nickel ochre, but appears to contain no other metallic substance except iron.

It occurs at Braunsdorf and Schneeberg in Saxony, in veins.

Sp. 14. Arseniat of Iron. *Wurfelerz*, Wern.

Its colour is dark brownish green, or brownish yellow. It occurs in mass and crystallized in cubes, either perfect or with the solid angles replaced by equilateral triangular planes. The planes of the crystals are smooth and shining. Internally it is glistening, with a vitreous lustre.

Its fracture is imperfectly foliated; its fragments are indeterminate. It is translucent; is a little harder than calcareous spar, and brittle. Sp. gr. 3. By decomposition it acquires a deep brownish-red colour, and at length becomes pulverulent.

Before the blowpipe it melts and gives out arsenical fumes. Its component parts, according to Chenevix, are

Arsenic acid	31.
Oxyd of iron	45.5
Oxyd of copper	9.
Silex	4.
Water	10.5
	100.0

The copper and silex appear to be entirely casual, for an analysis by Vauquelin presented the following results.

Arsenic acid	18.
Oxyd of iron	48.
Water	32.
Carbonat of lime	2
	100

It has been found hitherto only in veins in Carrarach, Tincroft, and Muttrel mines in Cornwal.

§ 2. *Analysis and Assay of Iron ores.*

1. The experiments on which Mr. Howard and Proust have founded their analyses of the *meteoric native iron* have been related in the preceding section. A method to the full as compendious and more satisfactory may however be deduced from Klaproth's very valuable analysis of chrysoprase.* (*a*) Let the iron be dissolved in moderately strong nitric acid, (*b*) then add liquid and perfectly caustic ammonia to supersaturation: after digesting the mixture a little while in a heat lower than that of boiling water, pour off the fluid part and repeat the digestion with ammonia as long as this latter acquires a blue colour. The insoluble portion is oxyd of iron, (*c*) which may either be heated with a little wax in a covered crucible and thus reduced to the state of magnetic oxyd, of which 100 parts indicate 73 of metallic iron; or it may be mixed with a little nitric acid and kept for a few minutes in an open crucible at a low red heat, by which it will be changed to the perfect red oxyd, of which 100 parts indicate 52. of iron. The ammoniacal solution contains the nickel, the amount of which may be thus estimated. (*d*) Saturate the ammonia with nitric acid and decompose the green solution thus produced by pure prussiat of potash: a sea-green precipitate will be thrown down, which when ignited in a covered crucible becomes entirely attractible by the magnet, and of which ignited residue 3 parts indicate 1 of metallic nickel.

In order to analyse the *proper native iron*, the best way of proceeding appears to be, (*a*) to dissolve the whole in dilute nitric acid; (*b*) then to separate the lead in the state of sulphat by sulphat of soda, and afterwards (*c*) by means of caustic fixed alkali at a boiling heat to throw down the mixed oxyds of iron and copper, from which the latter may be subsequently extracted by means of caustic ammonia.

2. *Pyrites* is magnetical or unmagnetical; if

* Analyt. Ess. i. p. 420.

the former, it may be either proper magnetical pyrites or common pyrites mixed with magnetic iron either in the metallic ſtate or in that of black oxyd. Muriatic acid will aſcertain to which of theſe three diviſions any particular ſpecimen belongs. If the magnetiſm is owing to black oxyd diſperſed through common pyrites, muriatic acid will not produce any inflammable gas by digeſtion with it; if the ſpecimen is a mixture of metallic iron and pyrites, the gas will be ſimple hydrogen: but if the ſubſtance under examination is magnetic pyrites, the gas will be ſulphuretted hydrogen.

Both ſpecies of pyrites are moſt conveniently analyſed in the following way. (*a*) The pyrites being previouſly reduced to a very ſubtle powder, is to be digeſted in moderately ſtrong nitric acid and boiled almoſt to dryneſs, a freſh portion of acid is then to be added, and this proceſs is to be repeated till the whole of the ſulphur is converted into ſulphuric acid. (*b*) The liquor being poured off, and the undiſſolved reſidue being thoroughly edulcorated, the waſhings are to be added to the liquor. (*c*) Into this is to be dropped a ſlight exceſs of carbonat of ſoda; and the precipitate, if there ſhould be any, is to be ſeparated. (*d*) The reſidual liquor, being perfectly neutralized by a little nitrous acid, is to be decompoſed by muriat of barytes added as long as any precipitate takes place. This precipitate is ſulphat of barytes, of which 100 parts indicate 14.5 of ſulphur in the ore. (*e*) The inſoluble reſidue (*b*) is to be digeſted with cauſtic ſoda, evaporated to dryneſs and ſlightly ignited, the precipitate (*c*) being then added, the whole is to be diſſolved in muriatic acid and boiled nearly to dryneſs, the affuſion of water will then leave the ſilex in the ſtate of a white inſoluble powder. (*f*) The muriatic ſolution being mixed to a ſlight exceſs with ammonia, the alumine and oxyd of iron will be precipitated together leaving the lime, if any happens to be preſent, in ſolution, whence it may be procured in the ſtate of carbonat by any mild alkali. (*g*) Laſtly, the iron and alumine are to be ſeparated either by boiling in nitric acid, which will diſſolve the earth and leave the metallic oxyd untouched, or by digeſtion in cauſtic ſoda or potaſh, which will produce a ſimilar effect.

3. *Magnetical Ironſtone*, *Specular Iron ore*, and *Red Ironſtone*, as far as they have been examined, appear to be compoſed of oxyd of iron with a ſmall caſual quantity of ſilex and alumine. They are for the moſt part with difficulty and imperfectly acted on by acids alone; the beſt method of proceeding in their analyſes is therefore the following. (*a*) Let the ore be reduced to a very fine powder and heated in a ſilver crucible with liquid cauſtic ſoda; when the whole of the moiſture is evaporated, let the remaining matter be ignited to a low degree for a few minutes; then diſſolve the whole contents of the crucible in dilute muriatic acid and evaporate the ſolution nearly to dryneſs; boil the reſidue in diſtilled water ſharpened with a little muriatic acid, and the ſilex will remain behind undiſſolved. (*b*) The ſolution being reduced to a moderately ſmall compaſs, add cauſtic ſoda to a ſlight exceſs and boil it upon the precipitate thus produced: the precipitate when edulcorated is pure oxyd of iron; which may be reduced to the magnetic ſtate and then eſtimated, as we have already mentioned in paragraph 1 of the preſent ſection. (*c*) The alkaline ſolution contains the alumine, which may be ſeparated by muriated ammonia, and then waſhed and ignited.

Black Ironſtone and *Brown Ironſtone*, as to compoſition, differ from the preceding only in containing manganeſe, the ſame method of analyſis may therefore be applied to theſe as to the former, with this difference, that as the precipitate (*b*) will in this caſe be a mixture of the oxyds of iron and manganeſe, an additional proceſs will be requiſite to ſeparate them. This may be effected with conſiderable exactneſs by diſſolving the mixed oxyds in muriatic acid and adding to the hot ſolution cauſtic ſoda drop by drop till the liquor becomes colourleſs, or till the precipitate that falls down at each addition of alkali begins to be white; thus the oxyd of iron will be thrown down and the manganeſe will remain in ſolution, which latter may be procured after the removal of the iron by continuing to add ſoda till no further precipitate is occaſioned. Another and equally exact method of ſeparating theſe two oxyds is by adding to the muriatic ſolution ſuccinat of ſoda, which precipitates the iron but does not affect the manganeſe.

4. *Spathoſe Ironſtone* may contain carbonic acid, the oxyds of iron and manganeſe; lime, magneſia and barytes probably in the ſtate of carbonat, a little ſilex and alumine. It may conveniently be analyſed in the following way. (*a*) Being reduced to extremely fine powder let it be digeſted in muriatic acid with a little nitric acid, a ſlow effervescence will take place and the carbonic acid may be eſtimated by the loſs of weight, or more exactly by collecting the gas in a mercurial pneumatic apparatus, and

then separating the carbonic acid by limewater. (*b*) The portion of the ore that is insoluble in the muriatic acid digested two or three times upon it is silex. (*c*) The muriatic solutions and washings being mixed are to be concentrated by evaporation and decomposed at a boiling heat by caustic soda in excess: (*d*) the precipitate and supernatant fluid being boiled together for a short time the alumine alone will be dissolved. (*e*) The insoluble portion being well washed is to be ignited and abstracted once with nitric acid, by which the lime, barytes and magnesia will be dissolved, and the oxyds of iron and manganese will remain behind. (*f*) These oxyds may be separated by digesting the mixture at a very gentle heat with dilute nitric acid and a small piece of sugar, the manganese will be totally taken up and the remaining pure oxyd of iron may be brought to the magnetic state by being heated with wax. (*g*) The nitrat of manganese of the foregoing process being mixed with carbonated soda a precipitate takes place, which after washing and drying at a heat below redness, is pure carbonat of manganese, of which 100 parts indicate 55. of reguline manganese. (*h*) The nitric solution of process (*e*) being considerably diluted with water, is to have sulphuric acid dropped in as long as any precipitate is formed, this is sulphat of barytes; which being removed, the other earths are to be thrown down by a carbonated alkali; are to be again dissolved in dilute sulphuric acid, and the sulphats of lime and magnesia thus produced being precipitated by alcohol are finally to be separated from each other by cold water, which will dissolve out the sulphat of magnesia without taking up any considerable quantity of the other.

5. The *argillaceous* and *bog ores*, the *blue* and *green martial earths*, contain a part or the whole of the following substances, viz. oxyds of iron and manganese, phosphat of iron, silex, alumine, and lime. These may be separated in this manner. (*a*) Having pulverized and ignited the ore, abstract it twice or thrice with nitric acid; then pour off the acid and wash the residue with a little more strong nitric acid: (*b*) add these acids together and evaporate almost to dryness. Then wash the residue with cold water and the phosphat of iron will remain behind. (*c*) Ignite the insoluble residue of (*a*) with caustic soda and separate the silex in the usual way by muriatic acid. (*d*) Mix together the nitric and muriatic liquors and boil them with an excess of caustic soda, the alumine will be taken up and the metallic oxyds and lime will be precipitated. (*e*) This compound precipitate being ignited and abstracted with nitric acid, the lime will be dissolved out; and nothing being now left but the oxyds of iron and manganese, these may be separated according to process (*f*) of the preceding paragraph, or by either of the methods described at the end of par. 3.

6. The *Arseniat of Iron*, though it consists essentially only of arsenic acid and iron, also contains accidentally silex and copper. It is conveniently and expeditiously analysed by Mr. Chenevix[b] in the following manner. The ore being pulverized and exposed to less than a red heat loses its water of crystallization. The residue being boiled with caustic potash, the alkaline solution is to be separated by filtration, and neutralized with nitric acid: being then treated with nitrat of lead, a precipitate of arseniat of lead takes place, of which 100 parts indicate 33 of arsenic acid. To the residue insoluble in potash muriatic acid is to be added, which will take up the iron and copper, leaving the silex behind. The muriatic solution being then supersaturated by ammonia, the oxyd of iron is precipitated, and the oxyd of copper is retained in solution by the alkali.

Having shewn the method to be pursued in the *analysis* of the various species of iron ores, we now proceed to treat of the method of *assaying* them, which for practical purposes is sufficiently accurate and even more satisfactory than a regular analysis. The three first and the three last species are never employed by the manufacturer of iron, the eight intermediate ores therefore are all that we have at present any concern with.

The ancient metallurgists, such as Cramer, Gellert and others, recommend the use of very active saline fluxes in the assay of iron ores; for this however there seems no sort of necessity, as the high degree of heat which is absolutely required to bring the metallic part of the ore into fusion will also vitrify the earthy parts by the assistance of lime and bottle glass, without having recourse to borax or any alkaline salt.

The richest varieties of the magnetic iron-stone, especially the iron-sand, may be assayed by mixing them when finely pulverized with about $\frac{1}{10}$ of charcoal or twice the quantity of fine sawdust and subjecting the mixture in a covered crucible to the full action of a powerful wind furnace for about an hour: the iron will be found collected into a somewhat irregular button beneath a small quantity of cellular scoriæ. This very simple mode of proceeding however

[b] Phil. Trans. for 1801, p. 220.

can only be had recourſe to when the proportion of earthy matter in the ore is very ſmall, and even then it will be better to add to the materials ſome green bottle glaſs, finely pounded, in weight equal to about one-half of the ore. The common magnetic ironſtone contains a conſiderable proportion of earth, chiefly ſilex, and may be moſt effectually and eaſily aſſayed by means of the following reducing flux. For every 8 parts of ore take 8 of bottle glaſs, 6 of limeſtone or chalk, and 1 of charcoal: mix the whole accurately together along with the ore, and heat it for a full hour in a wind furnace. If the operation has been properly conducted the iron will be found in the form of a well defined button, covered by a compact vitreous ſlag nearly of the colour of common green glaſs.

The ſpecular iron ore generally contains a portion of ſulphur from the caſual admixture of pyrites; it muſt therefore be roaſted at a moderate red heat as long as any ſulphureous odour is perceptible, after which, being mixed with 8 parts of bottle glaſs, 6 of chalk, and 1¼ of charcoal to ⅝ of the ore, it is to be fuſed as already mentioned.

The red, brown and black ironſtones may be treated as the preceding.

The ſpathoſe ironſtone requires no roaſting, and is beſt aſſayed by reducing it to powder and placing it in a crucible, lined with a mixture of charcoal and a little clay, and then covering it with ¼ of its weight of calcined borax.

The argillaceous and bog ores after roaſting may be mixed with 8 parts of bottle-glaſs, 7 of chalk, and 1½ of charcoal to 8 of ore, and fuſed in an unlined crucible; diminiſhing the proportion of chalk in thoſe varieties that contain a conſiderable quantity of calcareous earth.

§ 3. *Reduction of the Ores of Iron.*

The ancient and modern methods of extracting iron from its ores differing very materially from each other, it will be neceſſary to treat of them ſeparately.

Iron as it exiſts in the ore, whether in a ſtate of greater or leſs oxydation, is capable of being brought to the metallic ſtate when heated in contact with charcoal, by a much lower temperature than is required for its actual fuſion, and the iron being brought to this ſtate, the earthy matter with which it is mixed may be vitrefied by the addition of a proper flux, ſo as to allow the particles of metallic iron to ſubſide in conſequence of their ſuperior ſpecific gravity to the bottom of the maſs, although they are only in that ſoft paſty ſtate which common bar iron exhibits when it is at a white heat. Now the blowing machines of the ancient metallurgiſts being greatly inferior to thoſe which are employed at preſent, they were obliged to make uſe only of the richeſt and moſt eaſily reducible ores, and even theſe they were never able properly ſpeaking to fuſe in quantity, ſo that *caſt iron* was a modification of this metal wholly unknown to them.

That iron which was eſteemed the beſt was prepared in the following manner.[a] A maſs of brickwork was raiſed 5 feet in length and breadth and 3½ feet high, reſembling a ſmith's hearth, except that in the middle of this was ſunk a cupſhaped cavity or crucible, one foot in depth and half a foot wide, in the upper part of which was made a hole opening into a channel through the brick work. This hole being cloſed with clay, the crucible was filled with lighted charcoal heaped up ſo as to be above the level of the hearth; a blaſt of air was then admitted through a pipe let into the wall in the ſame manner as a ſmith's forge, and ſo contrived that the focus of the blaſt ſhould be juſt above the centre of the crucible. Charcoal alone was added from time to time, till the heap became thoroughly hot, and then at the diſcretion of the workmen the ore, in very ſmall pieces, unroaſted but mixed with unſlacked quick-lime, was laid on alternately with the charcoal. As ſoon as it had deſcended low enough to be within the immediate influence of the blaſt (which in a furnace of this conſtruction would be in a few minutes) the lime and earthy part of the ore became fuſed into a ſlag and inveloping the iron now in a metallic ſtate, ſunk down into the crucible, diſplacing the charcoal with which it had been at firſt charged. The matter remaining at reſt in the crucible gave an opportunity to the particles of iron to ſink to the bottom, which they did in greater or leſs proportion according to the fluidity of the ſlag and the compleatly metallic ſtate of the iron. After this proceſs had been going on for the ſpace of from eight to twelve hours, the crucible became filled with melted matter: at this time the hole which had been at firſt ſtopped up with clay was opened by means of an iron bar introduced through the channel in the brick-work, and the ſcoriæ immediately flowed out, leaving the iron behind covered with hot charcoal. The blaſt being ſtopped, the furnace ſoon got ſufficiently cool to allow the workmen

[a] Agricola de re Metall. p. 337.

to take out the iron, which was found imperfectly concreted together into a mafs nearly of the fhape of a wooden bowl: this being tranſferred to an anvil was firſt carefully hammered with wooden mallets to break off the encruſting ſcoriæ and render it ſufficiently compact to bear the tilt hammer, to which it was next ſubjected: being then divided into five or ſix pieces, each was ſeparately forged into a bar, and thus the operation was finiſhed. The iron thus obtained was extremely tough and hard but difficult to work, and was in great requeſt for helmets and other articles of defenſive armour, and in general for all purpoſes where toughneſs and hardneſs united were particularly required. The rich quality of the ore and the circumſtances in which it was reduced were probably the chief cauſes of the excellence of this kind of iron; a peculiarity however in the method of forging it may alſo have ſomewhat contributed to this; for while it was under the tilt-hammer, an aſſiſtant ſtood by with a ladle of water, with which he ſprinkled the bar as often as it was ſtruck by the hammer.

The poorer ores which were incapable of being ſmelted in the above method, were firſt picked, waſhed and roaſted, then reduced to pieces no larger than hazle-nuts, and reduced (no doubt with the addition of lime) in blaſt furnaces from ſeven to eight feet high and ſhaped like a chimney. In theſe a conſiderably greater heat could be produced than in the former, but it does not appear that the metal when taken out of the furnace was in the ſtate of caſt iron; certain it is that it was always allowed to cool there and was never run into pigs as is the modern practice.

Some ores that are very rich and yield a ſoft iron have been occaſionally wrought in a manner ſtill more ſimple than either of the proceeding. The rich ſpecular ore of the iſland of Elba in particular, appears formerly to have been worked to a conſiderable extent in this, which if not the earlieſt is certainly the rudeſt method that has hitherto been deviſed. The ore being broken into ſmall pieces is heaped upon a bed of charcoal in a very ſimple reverberatory furnace. When the whole has been glowing hot for ſome time, the pieces being now ſoft and at a welding heat, are by the dexterous management of the workmen brought in cloſe contact with each other by means of an iron bar; they are then lightly hammered while ſtill in the furnace, and thus the whole maſs acquires ſufficient compactneſs to be removed to the anvil without falling to pieces; it is now hammered with a gradually increaſing force, the earthy impurities are thrown off together with the ſcales of black oxyd, the lump is divided into pieces of a convenient ſize, which by repeated heating and hammering are drawn into bars. The rich red hæmatite, as appears from an experiment of Mr. Muſhet, is capable of being manufactured in the ſame way.

Theſe ancient methods have gone into diſuſe, not becauſe the quality of the iron thus produced was to be objected to, but becauſe the time and fuel conſumed were enormous, and the iron that remained in the ſcoriæ amounted at leaſt to one half of the original metallic contents of the ore.

The modern methods of reducing the ores of iron are principally two; depending on the nature of the fuel made uſe of. In England and Scotland the fuel is for the moſt part coak; but in the reſt of Europe, charcoal: and the proceſſes in the founderies where the latter is employed being the moſt ſimple, we ſhall commence with this method.

The beſt Swediſh bar iron, named in the market Oregrund iron, from the port whence it is ſhipped for the Engliſh market, is entirely prepared from the magnetic ironſtone of Dannemora. The forges and founderies where it is manufactured are thoſe of Soderfors and other places in the province of Roſlagia, and the moſt approved proceſſes that it undergoes for this purpoſe are the following. [b]

The ore in moderately large pieces, ſuch as it comes from the mine, is firſt roaſted. For this purpoſe an oblong coffer of maſonry, eighteen feet long, fifteen wide and about ſix in depth, open at top and furniſhed with a door at one of its ſmaller extremities, is entirely filled with logs of wood, over this the ore is piled to the heighth of from five to ſeven feet, and is covered with a coating of ſmall charcoal almoſt a foot and a half in thickneſs. Fire is then communicated to the bottom of the pile by means of the door juſt mentioned, and in a ſhort time the combuſtion ſpreads through the whole maſs: the ſmall quantity of the pyrites that the ore cantains is decompoſed by the volatilization of the ſulphur, the moiſture is alſo driven off, and the ore from being very hard and refractory becomes pretty eaſily pulverizable. In the ſpace of twenty-four hours the roaſting is completed, and the ore when ſufficiently cool is transferred to a ſtamping-mill,

[b] Jars Voyages Metallurg. i. p. 127.

where it is pounded dry, and afterwards ſifted through a network of iron, which will not admit any piece larger than a hazle nut to paſs. It is now ready to be ſmelted.

The ſmelting-furnace is a ſtrong quadrangular pile of maſonry, the internal cavity of which though ſimple in form is not very eaſily deſcribed: it may be conſidered however in general as repreſenting two irregular truncated cones joined baſe to baſe: of theſe the lower is ſcarcely more than one-third of the length of the upper, and is pierced by two openings, through the upper of which the blaſt of wind from the blowing machine is admitted into the furnace, and from the lower the melted matter, both ſcoriæ and metal, is diſcharged from time to time at the pleaſure of the workmen. The furnace is firſt filled with charcoal alone and well heated, after which alternate charges are added of ore, either alone, or mixed with limeſtone if it requires any flux, and charcoal: the blaſt is let on and the metal in the ore being highly carbonized in its paſſage through the upper part of the furnace is readily melted as ſoon as it arrives in the focus of the blaſt, whence it ſubſides in a fluid ſtate to the bottom of the furnace covered with a melted ſlag. Part of the clay that cloſes the lower aperture of the furnace is occaſionally removed to allow the ſcoriæ to flow out, and at the end of every ninth hour the iron itſelf is diſcharged into a bed of ſand where it forms from ten to twelve ſmall pigs. As ſoon as the iron has flowed out the aperture is cloſed again, and thus the furnace is kept in inceſſant activity during the firſt ſix months in the year; the other ſix months are employed in repairing the furnaces, making charcoal and collecting the requiſite proviſion of wood and ore.

The next proceſs towards the converſion of pig into bar iron is refining. For this purpoſe a furnace is made uſe of reſembling a ſmith's hearth, with a ſloping cavity ſunk from ten to twelve inches below the level of the blaſt-pipe. This cavity is filled with charcoal and ſcoriæ, and on the ſide oppoſite to the blaſt-pipe is laid a pig of caſt iron well covered with hot fuel. The blaſt is then let in and the pig of iron being placed in the very focus of the heat ſoon begins to melt, and as it liquefies runs down into the cavity below; here being out of the direct influence of the blaſt it becomes ſolid, and is then taken out and replaced in its former poſition, the cavity being again filled with charcoal; it is thus fuſed a ſecond time, and after that a third time, the whole of theſe three proceſſes being uſually effected in between three and four hours. As ſoon as the iron has become ſolid it is taken out and very ſlightly hammered to free it from the adhering ſcoriæ; it is then returned to the furnace and is placed in a corner out of the way of the blaſt and well covered with charcoal, where it remains till by farther gradual cooling it becomes ſufficiently compact to bear the tilt-hammer. Here it is well beaten till the ſcoriæ are forced out, and is then divided into ſeveral pieces, which by a repetition of heating and hammering are drawn into bars, and in this ſtate it is ready for ſale. The proportion of pig iron obtained from a given quantity of ore is ſubject to conſiderable variation from a difference in the metallic contents of different parcels of ore and other circumſtances, but the amount of bar iron that a given weight of pig-metal is expected to yield is regulated very ſtrictly, the workmen being expected to furniſh 4 parts of the former for 5 of the latter, ſo that the loſs does not exceed 20 *per cent.*

The method of preparing bar iron in all the other countries of Europe where charcoal is the fuel made uſe of, is upon the whole very ſimilar to that which we have juſt detailed, allowing for a few variations according to the different ſpecies of ore that are employed. But in Great Britain the number of charcoal furnaces is trifling compared with thoſe where coak is uſed, and the adoption of this kind of fuel has led by neceſſity to a method of manufacturing iron, quite peculiar to this country, and wholly inapplicable to thoſe eſtabliſhments that are carried on by means of charcoal. Each method has its peculiar advantages and diſadvantages; for if in quantity of produce from each forge the Britiſh claims the ſuperiority, yet this is probably more than counterballanced by the inferior quality of the metal, the greater multiplicity of apparatus, and conſequently the larger capital laid out, and the ſmaller proportion of iron procured from a given weight of ore. The method, however, purſued by the Britiſh manufacturers is not a matter of choice, but has been forced upon them by the deficiency of wood. They muſt either almoſt entirely abandon this important branch of metallurgy, or ſubſtitute coak with all its inconveniences to charcoal. Thus circumſtanced, much ſkill and ingenuity has been employed by them in overcoming the peculiar difficulties with which they have had to contend, and in making the moſt of the peculiar advantages connected with this mode of working, and upon the whole with ſo much ſucceſs as to enable the Britiſh manufactured iron to enter into competition

with every other kind except the very beſt Norwegian and Swediſh.

The common and nodular argillaceous ironſtone are the prevailing kinds of ore made uſe of in the coak ſmelting works, partly becauſe theſe are really better fitted, with this fuel, to produce iron of a good quality than the rich hæmatites of Lancaſhire, Cumberland and Devonſhire, and partly becauſe this kind of ore being uſually found to accompany the ſeams of coal, it may be procured at little expence, and the ſame ſituation that is well adapted for a ſupply of fuel is equally convenient for abundance of ore.

The firſt proceſs that the ironſtone undergoes after it has been broken into pieces not larger than an egg, is roaſting. This is ſometimes performed in cup-ſhaped kilns, the bottom being occupied by lighted coals and the kiln then filled up with ore, which by the time that the fuel is conſumed is found to be ſufficiently torrified. The moſt uſual way however of burning ironſtones is the following. Upon an oblong piece of firm and level ground is laid a bed of ſmall coal from four to eight inches in thickneſs; upon this is placed a ſtratum of ironſtone compoſed of pieces as nearly as poſſible of the ſame ſize, and from 18 inches to two feet thick: the upper ſurface of this is then rendered more compact by filling up the interſtices with ſmaller pieces of ore. Upon this reſts a layer of ſmall coal not more than two inches thick, and on this as a baſe, is reared a gradually diminiſhing pile of ore ſo as to reſemble the ridge of a houſe; finally, the whole external ſurface receives a compleat covering of ſmall coals and coal duſt. The pile is kindled by applying burning coals to the lower ſtratum, which by degrees ignite the whole maſs. The breadth of the pile at the bottom varies from 10 to 16 feet, the uſual height is about five feet, and the length varies from 30 feet to 60 yards. When the coals are conſumed the pile gradually cools, and in eight or ten days may be wheeled away to the furnace.[c]

The ore if well roaſted will now be of a reddiſh brown colour, of diminiſhed ſpecific gravity and will have become magnetical, the ſulphur, water, inflammable matter, and carbonic acid that it originally contained, will have been diſſipated, and it is now ready to be ſmelted.

The furnace reſembles externally a truncated quadrilateral pyramid of conſiderable height in proportion to its thickneſs, it is built of the ſtrongeſt maſonry, with contrivances to obviate the danger of its cracking by the expanſion that takes place when it is heated. The interior of the furnace conſiſts of the five following parts, reckoning from the bottom upwards.

Firſt the *hearth*, compoſed of a ſingle block of quartz grit about two feet ſquare: upon this is erected what in France and Germany is called the *crucible*, which is a four-ſided cavity ſix feet ſix inches high, ſlightly enlarging upwards ſo as to be two feet ſix inches ſquare at the top: the part above, called the *boſhes* is in the ſhape of a funnel or inverted cone, eight feet in perpendicular height, and twelve feet in diameter at the top; this terminates in the *cavity* of the furnace which is of a conical figure, thirty feet high, and three feet diameter at the top; from this part it enlarges into a funnel ſhaped *chimney* about eight feet high and ſixteen in diameter at its mouth. The lining from the hearth to the top of the boſhes is compoſed of large blocks of quartz grit, and that of the cavity of the furnace is formed of fire bricks 13 inches long, and three inches thick. About two feet above the hearth is a round aperture called the *Tuyere*, made in one of the ſides of the crucible to admit the extremity of the blaſt pipe, through which the air in a high ſtate of compreſſion is forced into the furnace; and at the bottom of the crucible is an aperture through which the ſcoriæ and melted metal are from time to time diſcharged. A furnace of this conſtruction, if it meets with no accident, may be kept in conſtant work for three years or more without requiring any repairs.

The furnace is charged at the chimney by regular intervals with coak, iron ore, and limeſtone in the proportion of about 4 of the firſt, $3\frac{1}{2}$ of the ſecond, and 1 of the third, by weight, care being taken ſo to regulate the frequency of the charges, as that the furnace ſhall be always full nearly to the top of the great cavity. The denſity of the blaſt and the form of the diſcharging pipe are ordered ſo that the chief focus of heat is about the bottom of the boſhes; hence the ore has to deſcend about 38 feet perpendicular, before it arrives at the place where the fuſion is effected. This does not happen in leſs than 48 hours, ſo that the ore is all this time in a ſtate of cementation at a high temperature in contact with the burning fuel, and in conſequence is almoſt ſaturated with carbon when it reaches the hotteſt part of the furnace. Being arrived at this place, the limeſtone flux, and the earthy particles of the

[c] Muſhet in Phil. Mag. iii. p. 205.

coaks and ore run down into a flag, the iron is alſo melted and more or leſs decarbonized, and in part oxydated by the blaſt inverſely according to the proportion of fuel with which it is mixed (for the oxygen of the air by preference unites with the looſe carbon of the coaks, rather than with that which has combined with the iron). The fluid maſs ſoon ſinks down below the influence of the blaſt, and while it remains in quiet at the bottom of the furnace the globules of iron are precipitated from the flag in which they were inveloped, and occupy the loweſt place, while the covering of ſcoriæ thus interpoſed between the metal and that portion of the blaſt which is reflected downwards, prevents it from ſuffering any further loſs of carbon. In proportion as the melted matter accumulates, the flag being the uppermoſt, flows out at the aperture made for this purpoſe, and the iron is let out at regular intervals into furrows made in ſand, where it forms what is called pig iron, or into a large reſervoir whence it is poured by means of ladles into moulds, forming all the various articles of caſt iron ware, from cannons and ſteam engine cylinders, to fire grates and common iron pots.

The great object of the manufacturer is, with a given quantity of fuel to obtain as large an amount as poſſible of highly carburetted caſt iron, as this is the kind which bears the higheſt price in the market: but as from various cauſes the iron is generally found to be more or leſs decarburetted, it becomes a matter of conſiderable importance to aſcertain by external characters the principal changes induced by a progreſſive diminution of carbon in order that the value of any particular ſample may be correctly and expeditiouſly aſcertained. By long and careful obſervation it has been found ſufficient for all practical purpoſes to arrange the ſeveral kinds of caſt iron under one or other of the four following ſubſpecies.

1. *Smooth faced Iron*, or *No.* 1. of the manufacturers. This ſeems to be compoſed of iron nearly ſaturated with carbon, and mixed with a comparatively ſmall proportion of oxyd and earthy impurities. Its upper ſurface is ſmooth and convex, entirely free from oxyd, and often covered with a thin cruſt of plumbago: it preſents a coarſe granular fracture with a brilliant metallic luſtre and a dark blue colour.

2. *Good melting pig Iron*, or *No.* 2 of the manufacturers. This differs from the preceding in containing probably a ſmaller portion of carbon and a larger admixture of oxyd of iron. Its upper ſurface is ſlightly convex and full of ſmall cavities: its fracture is coarſe granular towards the centre of the pig, but the concretions manifeſtly diminiſh in ſize as they are ſituated nearer the ſurface; its colour is dark-grey inclining to blue.

3. *Grey Iron*, or *No.* 3 of the manufacturers. In this the amount of carbon is ſtill further diminiſhed. Its upper ſurface is level, ſometimes ſlightly concave, and preſents more and larger cavities than the preceding, it is ſlightly oxydated ſuperficially; its fracture is fine granular, and its colour is light grey.

4. *White Iron, forge pigs, ballaſt Iron.* In this the quantity of combined carbon is ſmaller and the admixed oxyd larger than in any of the preceding. Its upper ſurface is concave, rough, and covered with a plate of oxyd; its fracture is compact ſometimes tending to ſtriated, its colour is tin-white, occaſionally mottled with grey.

We ſhall now proceed to ſtate in a general way, the circumſtances in the ſmelting which principally influence the quality of the produce. Much depends on the fuel: if the coaks are not perfectly made but retain a part of their bitumen, the whole maſs cakes together in the upper part of the furnace, and inſtead of deſcending regularly to the focus of heat, falls down by pieces, and at irregular intervals, ſo that part of the metal is detained too long before the blaſt, and in conſequence is decarbonized and oxydated, while other portions paſs ſo rapidly through the furnace as never to be thoroughly reduced, hence the amount of the produce is diminiſhed and its quality greatly deteriorated. Nor is it of leſs importance that the coak ſhould be perfectly dry when put into the furnace, otherwiſe the water which it contains will be decompoſed, the hydrogen and part of the oxygen will diſſolve their reſpective portions of carbon, and eſcape in a gaſeous ſtate, while the remainder of the oxygen will combine with the iron; which will thus be injured, not merely by the privation of carbon, but the poſitive addition of oxygen. It is further requiſite that the proportion of fuel be adapted to the richneſs of the ore, ſo that there may be ſufficient both to keep up the neceſſary degree of heat as well as to carbonize the metal: hence as the charges of ore and fuel are always proportioned by meaſure, if an ore ſomewhat richer than uſual happens accidentally to be employed without a correſponding addition of fuel, the produce though ſomewhat increaſed in quantity, will be more than equivalently reduced in quality. Another circumſtance that the manufacturer muſt carefully attend to, is the proper choice of ore with regard to fuſibility, for as it is not only requiſite that the iron

ſhould be melted, but alſo highly carbonized, and as coak gives off its carbon with much more difficulty than charcoal does, it is manifeſt that a very fuſible ore would melt long before it arrived at the focus of the furnace, and paſſing rapidly through, would reach the hearth without having had time to imbibe the proper quantity of carbon. Hence it is that the rich hæmatites, although they afford an excellent quality of iron when ſmelted with charcoal, produce nothing but white iron when treated in the coak furnace; while on the other hand argillaceous ironſtone being much more refractory, does not melt till it comes into the very hotteſt part of the furnace, and therefore has had full time to abſorb the deſirable quantity of carbon. Another thing to be attended to is the proper regulation of the blaſt, and this depends upon its dryneſs, its temperature, its compreſſion, and its direction. The dryneſs and temperature appear to be principally governed by the ſeaſon of the year, and therefore are but little capable of being modified by the manufacturer. It is plain that the dryer and colder the air is, the greater will be its effect on the combuſtion, and it is found by conſtant experience, that the produce of iron during the ſummer months is greatly inferior in quantity, and materially ſo in quality to that which is manufactured in the winter: a clear dry and ſevere froſt is the moſt favourable period in every reſpect for the working of the furnace, and a change to ſnow or rain is infallibly followed by a correſponding deterioration. The higher the temperature of the blaſt is when it is delivered into the furnace, the ſmaller (the degree of compreſſion and other circumſtances being equal) will be the quantity of oxygen contained in every cubic foot, and of courſe the vigour of the combuſtion. Nor is the force of the blaſt and its direction a ſubject of leſs importance; it is obvious that in proportion as the charge deſcends, the carbonaceous matter is continually diminiſhing, hence the proper ſituation for the focus of the blaſt is that part of the furnace, where, when the ore ſhall have arrived it will be fully carbonized and ſurrounded with a ſufficient quantity of fuel to excite an intenſe heat, and abſorb nearly the whole of the oxygen of the air, and thus prevent it from either oxydating the iron, or carrying off the carbon with which it may be combined. This preciſe ſituation, in a furnace properly conſtructed, will be found to be juſt within the expanſion of the boſhes; but as this is more than four feet above the tuyere hole, the blaſt muſt be delivered with great velocity and in a direction ſomewhat ſlanting upwards, in order that it may be reflected by the oppoſite wall of the crucible, and arrive at its proper place without undergoing any material decompoſition. When the blaſt enters too rapidly, and in too concentrated a ſtate, it renders the line of its paſſage before it is reflected ſo cool, that the deſcending ſlag which comes within its influence is ſuddenly ſolidified, and blown into a tube reaching perhaps half way acroſs the crucible through which the blaſt continues to ruſh, and in conſequence of this protection, is conveyed with greater preciſion, and in a leſs decompoſed ſtate into the upper part of the furnace. If after this the compreſſion of the air is ſomewhat diminiſhed, the tube ſtill remains firm, often for days together, and the furnace works in the beſt manner. But on the other hand, when too looſe and ſoft a blaſt is admitted, and more eſpecially if it is charged with moiſture, it is unable to reach the top of the crucible without being decompoſed, and the reflection which it undergoes from the wall of the crucible, weakens and diſperſes it to ſuch degree, that the combuſtion which ought to take place within the boſhes, now occupies the whole upper part of the crucible: in conſequence of this, the tube of ſcoriæ is preſently burnt away, the iron almoſt as faſt as it is melted is ignited and oxydized, the tuyere hole glows like the ſun with an intenſely vivid white light; the ſcoria from being yelloviſh white ſtreaked with blue, becomes green, brown, and finally black, nearly the whole of the iron in the ſtate of oxyd being taken up by it; the blocks of refractory gritſtone with which the lower part of the furnace is lined are worn into great holes, and in the ſpace of a few hours prodigious damage is ſuſtained.

There has been no regular analyſis of caſt iron, but from the phenomena that take place during its converſion into bar iron, which we ſhall proceed to deſcribe, it will be ſufficiently apparent what are its principal conſtituent parts.

One of the moſt obvious differences between caſt and bar iron, is the brittleneſs of the former and the malleability of the latter: this malleability has accordingly been adopted by the manufacturer as the eſſential character of bar iron, and as affording him a mode by which to judge of the efficacy of the means employed by him in reducing crude to malleable iron.

The firſt ſtep in the proceſs is refining[a]. For

[a] Collier in Mancheſter Tranſ.

this purpoſe the pigs are ſmelted in a refinery, (the conſtruction of which we have already noticed) by means of charcoal; and as ſoon as the metal is in fuſion it is let out into a mould of ſand to ſeparate the ſcoriæ that riſe to its ſurface, and in this ſtate is called a *half bloom*. As ſoon as it has become ſolid it is again tranſferred to the furnace and treated as before. Sometimes even a third fuſion is required before the iron ſhows ſufficient malleability to clot into lumps when broken down almoſt at a fuſing heat, by an iron bar. When it has acquired this conſiſtency, it is taken out in moderate ſized pieces, which being placed under the great forge or *ſhingling* hammer, are ſpeedily ſtamped into cakes about an inch in thickneſs. Several piles of theſe cakes about a foot high, are then laid on flat circular ſtones, and placed in the *balling* or reverberatory furnace, where they are ſtrongly heated. As ſoon as the whole acquires a paſty ſtate, one of the piles is taken out by a workman and drawn under the hammer into a ſhort bar: which being finiſhed, is applied to another of the piles, to which it preſently adheres: being then withdrawn, the new portion is welded firmly to the firſt by means of the hammer, and thus the bar is doubled in length; by repeating the ſame ſimple and ingenious operation the bar is made as long as its weight will conveniently allow. The cracks in the bar are then cloſed, and its tenacity is improved by heating it afreſh in a fire made of coal, called the *chaffery*, (chaufferie Fr.) and again ſubjecting it to the action of the forge-hammer. It is now in the ſtate of common bar iron, and ought to be entirely free from all earthy particles. After this, according to the uſe for which it is intended, it is transferred to the ſlitting mill; where it is laminated and cut up into bars and rods of various dimenſions, by which its toughneſs and compactneſs is much improved, and is then ready for the ſmith.

The above method is called *ſtamping*; but beſides this, there is another known by the name of *flouriſhing*, which requires a ſhort notice. In this the pigs of caſt iron when put into the refinery are kept for about two hours and a half in a paſty ſtate without actually melting, and at the end of this period the metal is taken out by ſhovels and laid on the open floor on a plate of caſt iron where it is beaten with hand-hammers in order to knock off the cinders and other adhering impurities. It is afterwards placed under the forge hammer and beaten, at firſt gently, till the whole maſs has acquired ſome tenacity, and then the middle part is drawn into a bar four feet long, terminated at each extremity by a cubical lump of rough iron: in this ſtate it is called an *Anconv*. It is now taken to the Chaffery, hammered afreſh, and the ends being alſo drawn down to the ſame dimenſions as the other part, the bar is compleated.

A third method of working iron, called *puddling*, was invented by Mr. Cort, (as appears from the ſpecifications of his two patents[e]) and is we underſtand coming into general uſe at Sheffield and other places. It is particularly characteriſed by combining the reverberatory with the finery furnace, and the whole proceſs is managed in the following manner. The pigs of caſt iron produced by the ſmelting furnace are broken into pieces, and are mixed in ſuch proportions according to their degree of carbonization, that the reſult of the whole ſhall be a grey metal. This mixture is then ſpeedily run down in a blaſt furnace, where it remains a ſufficient time to allow the greater part of the ſcoriæ to riſe to the ſurface. The furnace is now tapped, and the metal runs into moulds of ſand, by which it is formed into pigs about half the ſize of thoſe which are made at the ſmelting furnace: and theſe pigs when cold are broken into pieces.

A common reverberatory furnace heated by coal, is now charged with about 2½ cwt. of this half refined grey iron. In a little more than half an hour, the metal will be found to be nearly melted; at this period the flame is turned off, a little water is ſprinkled over it, and a workman by introducing an iron bar, or an inſtrument ſhaped like a hoe, through a hole in the ſide of the furnace, begins to ſtir the half fluid maſs and divide it into ſmall pieces. In the courſe of about fifty minutes from the commencement of the proceſs, the iron will have been reduced by conſtant ſtirring to the conſiſtence of ſmall gravel, and will be conſiderably cooled. The flame is then turned on again, the workman continuing to ſtir the metal, and in three minutes time the whole maſs becomes ſoft and ſemifluid, upon which the flame is again turned off. The hotteſt part of the iron now begins to heave and ſwell, and emit a deep-blue lambent flame, which appearance is called fermentation: the heaving motion and accompanying flame ſoon ſpreads over the whole, and the heat of the metal ſeems to be rather increaſed than diminiſhed for the next quarter of an hour: after this period the tem-

[e] Repertory III. p. 289 and 361.

perature again falls, the blue flame is leſs vigorous, and in a little more than a quarter of an hour the metal is cooled to a dull red, and the jets of flame are rare and faint. During the whole of the fermentation, the ſtirring is continued, by which the iron is at length brought to the conſiſtency of ſand, it alſo approaches nearer to the malleable ſtate, and in conſequence adheres leſs than at firſt to the tool with which it is ſtirred. During the next half hour the flame is turned off and on ſeveral times, a ſtronger fermentation takes place, and a loud hiſſing noiſe is perceived, the lambent flame alſo becomes of a clearer and lighter blue; the metal begins to clot and becomes much leſs fuſible and more tenacious than at firſt; the fermentation then by degrees ſubſides, the emiſſion of blue flame nearly ceaſes, the iron is gathered into lumps and beaten with a heavy-headed tool. Finally, the tools are withdrawn, the apertures through which they were worked are cloſed, and the flame is turned on in full force for ſix or eight minutes. The pieces being thus brought to a high welding heat are withdrawn and ſhingled; after this they are again heated and paſſed through grooved rollers, by which the ſcoriæ are ſeparated and the bars thus forcibly compreſſed acquire a high degree of tenacity.

The more welding and hammering that bar iron is ſubject to, the tougher it becomes and the more fibrous, or nervous as the French term it, is the fracture. Hence ariſes the ſuperiority of *Stub iron* to all the other varieties for barrels of fowling pieces and other uſes where extreme toughneſs is required. It is prepared in the following method. A moderately broad ring of the beſt Swediſh iron is placed horizontally and filled with old horſeſhoe nails (called ſtubs) ſet perpendicularly, till it can hold no more: a pointed bar of iron is then driven into the centre of the circle, and thus locks the whole faſt together. A welding heat is then applied, and the maſs is hammered very gently at firſt, till the nails and ring become compleatly united: it is then drawn down into bars and affords an iron of peculiar cloſeneſs, toughneſs, and malleability.

§ 4. *Manufacture and properties of Steel.*

Steel combines the fuſibility of caſt iron with the malleability of bar iron, and further poſſeſſes this very valuable property, that when heated and ſuddenly cooled, it becomes intenſely hard, and is therefore much ſuperior to ſimple iron for all kinds of cutting inſtruments, files and various other tools. In the preſent ſection we ſhall deſcribe the different methods of preparing and tempering ſteel, reſerving for the next ſection an enquiry into the chemical compoſition of this uſeful ſubſtance.

The moſt ancient way of making ſteel is probably that related by Agricola.[5] Take ſome highly carburetted bar iron, cut it into ſmall pieces and mix it with pulverized ſcoriæ, put the mixture into a crucible lined with charcoal, and bring it to a ſtate of fuſion in a blaſt furnace. When both the iron and ſcoriæ are thoroughly fluid, immerſe in this metallic bath four lumps of bar iron, weighing about thirty pounds each, and let them remain in this ſituation during five or ſix hours, ſtirring the bath occaſionally with an iron rod; by this time they will have become ſoft and ſpungy, upon which they are to be taken out and drawn down into bars by the forge hammer. As ſoon as this is performed, the bars ſtill hot, are to be plunged into cold water, by which they will be rendered brittle, and are then to be broken under the hammer into ſhort pieces. The crucible in the mean time is to be repleniſhed with the ſame mixture as before, and when its contents are become quite fluid, the pieces into which the bars have been broken are to be again immerſed till they become ſoft: each piece being then taken out and forged ſeparately into a ſlender bar, is to be cooled while yet glowing hot, in cold water, and the proceſs is finiſhed. The above method is we believe entirely obſolete, though with a few modifications that are ſufficiently obvious, it would in all probability be found highly advantageous.

The *native* ſteel of Eiſenhartz in Stiria has always been in high eſtimation ſince the eighth century, and is prepared directly from the ore nearly in the ſame manner as common bar iron.[h] The ore made uſe of is the Spathoſe Ironſtone, conſiſting of the carbonats of iron, manganeſe and lime, together with a mixture of clay: it is procured in vaſt abundance from the neighbouring hill of Arzberg, and care is taken not to uſe any that has not been expoſed for ſeveral years to the action of the air. No flux of any kind is neceſſary, and the fuel, which is charcoal, does not on an average exceed in weight one fifth of the ore. When a ſufficient quantity of melted matter is collected at the bottom of the furnace it is let out into a deep mould, where it remains quiet a few minutes to allow the ſcoriæ

[5] Beddoes in Phil. Tranſ. lxxi. p. 173. [6] De Re. metall. p. 344. [h] Jars voyages metallurg. I. Rambourg in Journ. des mines, No. 88 and 89. Haſſenfratz in An. de Chim. xix. p. 22.

to riſe to the ſurface: this being done, a little water is ſprinkled over it, which hardens the ſcoriæ and renders them eaſily removable: a ſecond but much thinner cruſt of ſcoriæ generally ſucceeds, which is got rid of in the ſame manner. A little water is now thrown on the melted metal itſelf, by which its ſurface is ſuddenly covered with a congealed cruſt about an inch thick; this is removed, and by repetitions of the ſame proceſs the greater part of the maſs is thus converted into theſe irregular plates: what remains is a maſs in the ſtate of half malleable iron. Theſe plates are transferred to the crucible of a refinery which has been previouſly lined with charcoal, and are covered with ſcoriæ and brought to a ſtate of fuſion, carefully obſerving however not to direct the blaſt from the bellows into the crucible, leſt the iron ſhould be decarbonized. After the whole has been in quiet fuſion for ſome time, the fire is ſlackened, and as ſoon as the metal has congealed the ſcoriæ ſtill fluid are let off. The maſs is then ſubjected to a ſecond fuſion in the refinery with the ſame precautions as at firſt, and is now ſufficiently purified to be forged: it is accordingly extended under the hammer and cut into bars which are examined by their fracture, and ſeparated according to their qualities, into hard ſteel, ſoft ſteel, and ſteely iron: the latter is reſerved by itſelf and uſed for pointing plowſhares and other coarſe work; but the others are made up into packets, obſerving to place the hardeſt ſteel on the inſide, which are then drawn into bars at a lower heat than that required for iron, and then the proceſs is compleat. Thus the whole art conſiſts in purifying the caſt iron, taking at the ſame time particular care that the carbon which it contains is not burnt away. If the original caſt iron is very highly carbonized it ſometimes happens that the ſteel retains too large a proportion of carbon, which is evinced in the refinery by its being more eaſily fuſible, and requiring a longer time to become ſolid again than uſual: this defect however is ſpeedily remedied by adding iron filings or ſcraps of bar iron, the quantity of which is regulated by the degree of fuſibility to be corrected.

If the manufacturer wiſhes to procure iron from this ore inſtead of ſteel, the only difference required in the treatment is to get rid of nearly the whole of the combined carbon by roaſting the plates in a reverberatory furnace before they are brought to the refinery, and by avoiding to line the crucible of the refinery with pounded charcoal. The iron thus produced is of an excellent quality.

The beſt of the Swediſh and Norwegian ores are occaſionally wrought into ſteel of a very good quality by nearly the ſame proceſs of manufacture, provided in the ſmelting a larger proportion than uſual of charcoal has been employed to enſure a highly carbonized metal.

The uſual method of converting iron into ſteel is by *cementation*[1]. For the purpoſes of manufacture, this is performed on large quantities at a time in the following manner. A cementation or converting furnace conſiſts of two parallel troughs, conſtructed of fire-brick, ſufficiently long to admit with convenience a common bar of iron; theſe troughs reſt upon a long grate from which flues proceed ſo as to diſtribute the heat as evenly as poſſible to every part: an arched vault is thrown over the top, and the whole is incloſed within a cone of maſonry as the glaſs houſe furnaces are. The bars of iron intended for cementation are of the very beſt quality, (in England none but the Swediſh Oregrund iron is employed for this purpoſe) and are carefully examined to aſcertain that they are quite free from cracks, flaws, and every appearance indicative of their not being compleatly malleable. The requiſite ſelection being made, a ſtratum of coarſely bruiſed charcoal is laid at the bottom of the cementing trough, upon which is arranged a layer of iron bars: to this ſucceeds another of charcoal, and ſo on till the trough is nearly filled, obſerving that the upper as well as the loweſt layer is charcoal: it is then covered with a mixture of hard rammed clay and ſand in order to exclude the air. A trough thus charged will contain from ſeven to ten tons of iron. The fire being lighted, the heat paſſes into the flues and raiſes the temperature of the troughs to a glowing red which is maintained for the ſpace of from ſeven to eleven days, according to the quantity of iron. At the extremity of each trough is a ſmall hole, through which two or three bars project a few inches in order that they may be occaſionally withdrawn to aſcertain the progreſs of cementation: when by the trial bars, it appears to be compleat, the fire is put out, and after the troughs are ſufficiently cool they are emptied of their contents. The form of the bars thus converted, remains unaltered, but their ſurface is covered over with bubbles or bliſters, whence the ſteel in this ſtate is called *bliſter ſteel*: it is heavier than the iron from which it was made on account of its having abſorbed a portion of carbon from the

[1] Collier in Manch. Tranſ. V. p. 122.

charcoal with which it was in contact, though this is by no means the only action that takes place in the process of steel-making, as we shall show in the next section. Blister steel is employed only for the coarsest purposes, such as pointing horses shoes, ploughs, and other agricultural instruments, &c. By being drawn down into smaller bars under the tilt-hammer, its texture is considerably improved, and it is known in the markets by the name of *tilted steel*. As repeated hammering improves iron, so it does steel: hence if a bar of highly carbonized blister steel is broken into very short pieces, and these being formed into small packets, are again welded together and drawn down into bars, which being again doubled together are welded and tilted, repeating the process two or three times, the result will be a very material improvement in compactness and toughness, and the metal will be found well qualified for swords and the larger articles of cutlery: this steel has long been prepared in high perfection in Germany, whence it is called *German steel;* it is also known by the name of *shear steel*.

This is the proper place to mention the process of *case-hardening*, which in fact is only an imperfect kind of cementation, converting little else than the immediate surface of the metal into steel, and therefore being performed not on the rough bar but the manufactured article. The cements or carbonaceous substances used on this occasion are bone shavings or turnings, horn cuttings, and old leather shoes. The work intended to be cased having been previously filed to the requisite shape, that there may be as little occasion as possible to apply the file afterwards, is laid together with the cement in a pan of plate-iron. A forge fire is then made of considerable size, and when the upper part has caked together it is carefully lifted off without breaking, the pan is laid upon the red coals and covered with the caked mass. In this state it remains for nearly two hours, without urging the fire. Small pieces of iron wire that have been previously introduced into the pan being withdrawn from time to time, are dipped while hot in cold water, and by the file and the character of the fracture, the progress of the cementation is determined. When the intended degree of carburation is obtained, the fire is increased and the articles as soon as sufficiently heated are taken out of the pan and plunged in cold water. The inferior kinds of table-knives and some surgical instruments, where a considerable degree both of toughness and hardness is required, are prepared in this way. [k]

The finest kind of steel however, called *English cast steel*, yet remains to be mentioned. It is commonly prepared by breaking to pieces the blister steel and then melting it in a crucible with a flux composed of carbonaceous and vitrefiable ingredients. When thoroughly fused it is cast into ingots, which by gentle heating and careful hammering are tilted into bars. By this process the steel becomes more highly carbonized in proportion to the quantity of flux, and in consequence is more brittle and fusible than before; it is inferior to the other kinds of steel in being incapable of welding either with iron or steel, but on the other hand surpasses them all in uniformity of texture, hardness, and closeness of grain, hence it is the material of all the finest articles of English cutlery. The composition of the flux used in preparing this steel is kept a secret among a few manufacturers, and in consequence various experiments have been instituted both here and elsewhere to discover either the same or an equally successful method of making this beautiful substance. In 1795, Clouet published the results of some valuable experiments, from which it appears that by simply fusing bar iron with charcoal a cast steel may be obtained more or less carburetted, according to the proportion of charcoal employed, and therefore possessing at pleasure in a greater or less degree the qualities of fusibility, brittleness and hardness: he also showed that the same effects may be produced by fusing bar iron with glass and charcoal, or the black oxyd of iron with the requisite proportion of charcoal alone, or by keeping in fusion for about the space of an hour a mixture of small bits of iron and equal parts of clay and marble or any other calcareous carbonat. [l] In 1800 Mr. Mushet took out a patent for preparing cast steel of various qualities by fusing bar iron with different proportions of charcoal, coinciding for the most part with the facts and principles before laid down by Clouet, and confirmed by his own experiments; [m] but whether the steel thus prepared is equal to the finest cast steel of Huntsman, has not we believe been as yet compleatly ascertained.

Steel is rendered hard by heating and then suddenly cooling it. The degree of hardness which it is capable of acquiring is in direct proportion to its fusibility, or in other words to the quantity of carbon with which it is combined; and the degree of hardness which in

[k] For the above and some other practical information contained in this article, the Authors are indebted to the professional liberality of Mr. W. H. Pepys. [l] Journal des Mines, No. 49. [m] Repertory, xiv. p. 176.

any particular inſtance is actually given to it is in proportion to the difference of temperature between the medium in which it is heated and that in which it is cooled; modified however by the capacity for heat and the conducting power of the cooling medium. Thus if ſteel is heated ſomewhat below the degree at which it melts and then transferred into oil at the temperature of 200°, the hardneſs thus acquired will be inferior to that which would have been obtained if water, or ſtill more ſo if mercury, at the ſame temperature had been made uſe of. Again, if inſtead of oil at 200° the ſame fluid at 40° had been employed, a greatly ſuperior degree of hardneſs would have been produced.

The hardneſs acquired by this method has generally been thus accounted for. The particles of the metal by being heated are placed at a greater diſtance from each other than before, and in proportion as this heat is again abſtracted, the attraction ſubſiſting between them will become efficacious, and they will approach nearer to actual contact; but the impetus with which this takes place will be in proportion to the difference of temperature, and therefore when red-hot ſteel is plunged in ice-cold mercury, the force or reſilient ſpring of its particles will be greater than if mercury at 200° had been made uſe of, and conſequently its hardneſs will alſo be greater. But this theory however ingenious is oppoſed by certain facts which perhaps may be found more conſonant with the following explanation of them.

If we take the ſpecific gravity of a piece of ſteel both when hardened and after it has been ſoftened by heating again and gradually cooling, we ſhall find that its bulk in the former caſe is greater than in the latter, whereas if the hardneſs of ſteel was owing to the rapidity and energy with which its particles collapſed on cooling, directly the reverſe of this ought to take place, the ſtate of greateſt hardneſs ſhould be that of the greateſt ſpecific gravity. So in like manner we find to be the caſe with glaſs; if a little of this in a melted ſtate is dropped into cold water it will prove very hard and brittle; but if the ſame piece is again heated red (without however in any degree ſoftening it) and afterwards allowed to cool gradually, its ſpecific gravity will have very notably increaſed, and it will have become tough and elaſtic. We may therefore conſider the hardening of ſteel to be cauſed by the contemporaneous expulſion of part of its heat and the fixation of its particles before they have had time to arrange themſelves and contract upon each other. Hence on the impreſſion of any external force, the particles that are ſtruck are not able to ſlide on each others ſurfaces, and thus diſtribute the impetus which they have received over the contiguous ones; or in other words the maſs becomes *harder* than it was before, hence alſo the whole force of a blow is borne by a comparatively ſmall number of inſulated particles, and theſe entirely giving way before a degree of percuſſion that might eaſily be ſuſtained by the whole when combined, thus produce the quality of *brittleneſs*.

If highly carburetted ſteel is made nearly as hot as it can bear without melting, and is then plunged in very cold water, it is apt to fly to pieces, and even if this does not take place the metal is not applicable to any uſe in this ſtate of extreme hardneſs, for the particles are placed ſo far aſunder that the whole has a ſtrong tendency to become crumbly, and will not bear a fine even ſharp edge. In the practice of the beſt manufacturers the hardening heat even for files, which are the hardeſt of all ſteel inſtruments, is not greater than a red viſible by daylight; and all cutting and elaſtic inſtruments require to be much ſofter. The various degrees of hardneſs neceſſary for different articles are not however given, as might at firſt be ſuppoſed, by the ſimple proceſs of hardening at the requiſite temperature, but by the compound method of firſt giving to every article nearly a file hardneſs, and then, by the ſubſequent proceſs of *tempering*, reducing the hardneſs to the particular degree neceſſary for each article.

Tempering conſiſts in ſoftening hardened ſteel by the application of a heat not greater than that which was employed in hardening it; for this purpoſe it is gradually heated more or leſs according to the temper required, and cooled again either gradually or rapidly, this making no difference, after which the ſteel is found to be ſoftened or tempered exactly in proportion to the heat which it has undergone. While the ſteel is tempering its ſurface diſplays a ſucceſſion of colours (ſuppoſed to ariſe from a commencing oxydation) in proportion as it becomes more and more heated, which the workmen in this metal have ingeniouſly taken advantage of as indicating and ſerving to denominate the degree of temper required for different articles. The firſt perceptible colour is a light ſtraw yellow, and this being produced by a ſmall degree of heat indicates the higheſt or hardeſt temper; to this ſucceeds a full yellow, then a brown, afterwards a reddiſh blue, then a light blue, and laſtly a full deep blue paſſing into black, which being the other extremity of the ſeries

denotes the loweſt degree of temper and a hardneſs only a little ſuperior to what the piece of ſteel would have acquired if when heated for the purpoſe of being hardened it had been allowed to cool gradually inſtead of being plunged into a cold liquid. The old method of tempering, and which indeed is ſtill practiſed by moſt manufacturers, is to lay the articles on a clear coal fire, or on a hot bar, till they exhibit the requiſite colour; but ſmall articles which were to be reduced to a blue temper were commonly *blazed*, that is they were firſt dipped in oil or melted greaſe, and then held over a fire till the oil became inflamed, and thus evaporated.

Some particular articles require a nicety of temper that is not very eaſily attained by truſting merely to the change of colour, a circumſtance that induced Mr. Hartley, in the year 1789, to take out a patent for a new and more accurate method. For this purpoſe a mercurial thermometer graduated as high as 600° is to be immerſed in an iron trough heated by a furnace or lamp placed below it and filled with fuſible metal, upon the ſurface of which the ſteel is to be laid, which may thus be tempered with great accuracy at any degree of the thermometer that the artiſt chuſes. Oil may be ſubſtituted to the fuſible metal, and the effect will be the ſame except that the ſteel being in this caſe tempered beneath the ſurface of the liquid, and of courſe out of the contact of atmoſpherical air, will not exhibit thoſe changes of colour which take place when the other methods are employed. The following table ſhows the temperature at which the various colours make their appearance.

430° to 450° indicates the ſeveral tints of ſtraw colour, and is the temper for razors and thoſe inſtruments which have a ſtout back ſupporting a keen and delicate edge.
470° correſponds with the full yellow, and is the proper temper for ſcalpels, pen-knives, and other fine-edged inſtruments.
490° indicates the brown yellow, and is the proper temper for ſciſſars and ſmall ſhears.
510° indicates the firſt tinge of purple, and is the temper for pocket and pruning knives
530° indicates purple, and is the temper for table and carving-knives.
550° to 560° indicates the different ſhades of blue, and is the temper for watch-ſprings, ſwords, and all thoſe inſtruments in which great elaſticity is required.
600° correſponds with black, and is the loweſt degree of temper.

One great advantage attending the uſe of caſt ſteel is its uniform quality: the carbon which it contains appears to be equally diſtributed through every part of the ſame maſs in conſequence of the fuſion that it has undergone: whereas both the natural ſteel and the ſteel of cementation are apt to contain veins of iron, either quite ſoft or at moſt very ſlightly carburetted, and thus a degree of imperfection and uncertainty is introduced extremely mortifying to the artiſt, and not unfrequently the occaſion of much labour in vain. It is therefore no ſmall benefit which Mr. Nicholſon has conferred on the workers in iron and ſteel by publiſhing a ſimple and effectual method of aſcertaining whether any particular bar is pure iron or ſteel, or a mixture of both. * The ſurface of the metal being cleaned with a file or with emery paper, is to be ſpread over with very dilute nitrous acid, by which the iron will be diſſolved, but the carbon will remain behind untouched; after therefore the acid has been allowed to act for a few minutes, the bar is to be put into clean water and moved about in it gently, that both the reſidual acid and the nitrat of iron may be waſhed away, care being taken not to touch the ſurface with the hand or any thing elſe that may rub off the carbon. The bar thus waſhed, if pure iron, will exhibit an uniform iron-grey colour; if it is pure ſteel, the colour of the ſurface will be black, the iron having been taken up by the acid and a thin coating of carbon remaining; but if it is a mixture of iron and ſteel the ſurface will be dotted or ſtreaked, thoſe parts which are ſteel being of a dull black, and thoſe which are iron exhibiting the uſual colour and luſtre of this metal.

Steel being conſiderably more expenſive than iron, it is cuſtomary in making the larger and coarſer kinds of cutting inſtruments to form only the edge of ſteel. The two bars of iron and ſteel are firſt welded together and afterwards forged into the requiſite ſhape in the uſual manner. Highly carbonized ſteel is however incapable of being thus united to iron, becauſe the ſame temperature at which iron welds freely is that at which this kind of ſteel enters into fuſion, and therefore the firſt ſtroke of the

* Nich. Phil. Journ. 4to. i. p. 470.

hammer will entirely ſhatter the ſteel and diſperſe it about in ſmall fragments. This however is a difficulty which it is well worth while taking ſome pains to overcome, as the efficacy and durability of inſtruments thus compoſed materially depends upon the goodneſs of the ſteel. The moſt effectual way hitherto diſcovered of uniting together iron and highly carbonized ſteel, is that publiſhed by Sir Thos. Frankland. The iron is to be raiſed to a welding heat, in one forge, and the ſteel is to be made as hot as it can bear without becoming very brittle, in another; both pieces are then to be quickly brought to the anvil and made to adhere together by gentle hammering.

Several curious pieces of work are made of iron and ſteel welded together, eſpecially the real Damaſcus ſword blades, which are believed to be compoſed of ſlips or thin rods of iron and ſteel bound together with iron wire, and the whole firmly cemented together by welding. The properties and external appearance of ſuch a blade correſpond very exactly with the ſuppoſed mode in which it is manufactured. Its colour is a dull bluiſh grey, it is ſcarcely harder than common ſteel from the forge, it is not eaſily bent, and when bent has no elaſticity to recover its original figure; but the circumſtance which principally characterizes it is the appearance of narrow waving lines not croſſing each other and chiefly running from heel to point; they are ill-defined and about the thickneſs of a harpſichord wire. This wavy appearance is not produced by any perceptible indentation of the ſurface but merely by a ſlight difference in the degree of poliſh or brightneſs, and therefore may be at once diſtinguiſhed from the falſe damaſking or etching by which other ſword-blades are made to reſemble the genuine Damaſcus ones. In the falſe Damaſcus blades the waving lines, called the *water*, are obliterated by grinding, but in the real ones, although the water is at firſt imperceptible after grinding, yet it may at any time be made to reappear by rubbing the blade with lemon juice, no doubt on account of the unequal action of this weak acid on a ſurface compoſed both of ſteel and iron. *

Beſides the varieties of ſteel that we have already deſcribed there yet remains one more, concerning which a few words will be neceſſary: this is Wootz.[k] The ſubſtance known by this name in India, is imported into this country in the form of round flat cakes about five inches in diameter and one inch in thickneſs. When cold it is uncommonly refractory, neither breaking nor bending under the hammer. It is not nearly ſo eaſy to be filed as either bar or caſt ſteel before theſe have been hardened: it takes an extremely high brilliant poliſh; its fracture is moderately cloſe, reſembling that of bliſter ſteel that has been heated and hammered a little. When nearly white hot it is malleable, but is much more likely to crack under this treatment than even caſt ſteel; it requires therefore much care, labour, and time to faſhion it into any required ſhape. When made white hot it exhibits the glaſſy ſmooth ſurface of welding iron, but when ſtruck very gently with a hammer, it cracks in many places, and by a harder blow is ſhivered to pieces. When brought to a high heat and quenched ſuddenly in cold water, it becomes harder than at firſt, though not equally ſo with the fineſt caſt ſteel in ſimilar circumſtances; but on the other hand, it is not capable of being ſenſibly ſoftened by annealing as the other varieties of ſteel are. At a high heat it is fuſible, and after being melted exhibits a cloſe compact grain, is conſiderably brittle, and bears a very near reſemblance to caſt ſteel. From its analyſis and other circumſtances it is conſidered by Dr. Pearſon as differing from ſteel only in containing a little oxyd of iron.

§ 5. *Compariſon and analyſis, of Caſt Iron, Bar Iron, and Steel.*

Notwithſtanding the cloſe attention of various eminent chemiſts to this important ſubject, much yet remains to be done before an entirely ſatisfactory theory can be formed to account for the different properties poſſeſſed by the various kinds of iron and ſteel. We ſhall endeavour to ſhow in the preſent ſection the progreſs that has already been made in this intereſting analyſis, and ſhall then point out ſome of the chief difficulties that yet remain to be overcome.

In all the varieties of iron and ſteel, the principal ingredient is metallic iron, and as this metal in the reguline ſtate alone has the property of giving out hydrogen gas while diſſolving in dilute ſulphuric or muriatic acids, the amount of inflammable gas thus produced has been adopted by Bergman, by Berthollet and Pearſon, as upon the whole the moſt ſatisfactory and compendious exponent of the quantity of reguline iron contained in any of the known varieties and forms of this metal. Thus a mixture of equal parts of reguline and oxydized iron by treatment with dilute ſulphuric acid, will produce only half the quantity of hydrogen

* Nich. Phil. Journ. 4to. i. p. 469.

[k] Pearſon in Phil. Tranſ. lxxv. p. 322.

gas that an equal weight of pure iron would. But this can be admitted to be a perfectly accurate mode of proceeding only where the mixture thus analyzed, contains nothing that is ſoluble in hydrogen gas at the temperature, and in the other circumſtances under which the experiment is performed. None of the kinds of manufactured iron is entirely free from carbon, and this acording to Berthollet[1] is taken up by the naſcent hydrogen as the metal diſſolves in the acid, whence originates a material ſource of error, the quantity of gas produced depending not merely on the proportion of iron, but alſo of carbon in the mixture. It appears from Berthollet's experiments that when caſt iron or ſteel is treated by dilute ſulphuric acid, at a boiling temperature, in proportion as the metal diſſolves, a black ſpungy matter is obſerved floating in the ſolution: the quantity of this increaſes till the proceſs is about half over, then it begins to diminiſh, and will be found to have entirely diſappeared by the time that the laſt portions of iron have diſſolved. This black matter is carbon, which being inſoluble in ſulphuric acid or ſulphat of iron, muſt neceſſarily have been taken up by the hydrogen. This accordingly is found to be the caſe, for the gas produced requires a greater proportion of oxygen for its combuſtion, and the reſult of the proceſs is a quantity of carbonic acid. This is further confirmed by an obſervation of Rinman's that the inflammable gas ariſing from the ſolution of ſteel, affords by combuſtion more fixed air than that which is produced from the ſolution of bar iron. From the numerous experiments of Berthollet on this ſubject, we have ſelected the ſix following as ſufficient for our purpoſe, and having converted the weights and meaſures into Engliſh, it appears that at 29.84 Bar. and 59° Fahr.

Grs.		
100 of grey caſt iron yield with diluted ſulphuric acid	104.8	oz. meaſures of inflammable gas.
100 of bar iron made from the preceding	111.5	do.
100 of Steel from the preceding	108.3	do.
100 of Sweediſh bar iron	114.	do.
100 of Steel from the preceding	106.7	do.
100 of white caſt iron from Eiſenerz	97.4	do.

It might at firſt be ſuppoſed that a given quantity of hydrogen would increaſe in bulk in proportion to the carbon taken up by it, the reverſe of this however is in fact the caſe: therefore if Swediſh bar iron be conſidered as the pure ſtate of this metal, repreſented by the number 114, the proportion of iron contained in an equal weight of ſteel made from the ſame will be more than 106.7, becauſe the former number indicates pure hydrogen, but the latter carburetted hydrogen.

Dr. Pearſon on the other hand, in his experiments on Wootz, aſſures us that when dilute ſulphuric acid is acting on ſteel at the common temperature, a quantity of black carbonaceous matter is ſeparated, which continues to augment ſo as to impede the effect of the acid; if at this period a lamp is applied, the increaſed temperature brings on a more rapid action, and the black ſediment appears rather to diminiſh in quantity. This diminution however Dr. P. attributes only to the ſolution of the iron with which the carbon was combined, and not to the ſolution of the carbon itſelf in the hydrogen: for, ſays he, the gas when burnt with oxygen procured from manganeſe, inflamed like common hydrogen, and whether procured by means of iron, or ſteel, or wootz, produced only a very ſlight turbidneſs with limewater; whereas carburetted hydrogen, prepared by paſſing ſteam through hot charcoal, being treated in the ſame manner, rendered the limewater quite milky. The proportions of gas from iron and ſteel were alſo remarkably leſs than thoſe mentioned by Berthollet. 100 grains of wootz by ſeveral experiments yielded from 78 to 84 ounce meaſures of gas. 100 grains of ſteel wire, alſo by various experiments, yielded from 83 to 86 ounce meaſures of gas. 100 grains of iron wire yielded from 86 to 88 ounce meaſures.

How much ſoever the experiments of Berthollet and Dr. Pearſon differ in other reſpects, yet we may infer that Swediſh bar iron contains a larger proportion of reguline iron than the other varieties of bar iron, that ſteel contains a ſmaller proportion than bar iron, that wootz contains a ſtill ſmaller proportion, that grey caſt iron is inferior in this reſpect to ſteel, and that white caſt iron is the leaſt pure of any.

We alſo learn that the lower the temperature is at which the ſolution of the iron is made, the purer is the hydrogen that is produced, and with

1 Mem. de l'Acad. for. 1786. p. 164.

proper care that the objections raiſed by Berthollet to the accuracy of this mode of proceeding, may be compleatly done away.

We have already mentioned that almoſt all the known varieties of iron and ſteel contain a larger or ſmaller proportion of carbon. The quantity of this in any particular ſample of metal may beſt be aſcertained by digeſting the metal in dilute nitro-muriatic acid which will leave untouched the carbon united with a little iron. This black inſoluble reſidue being waſhed in warm water and finally digeſted for a minute in weak ammonia, ſhould be heated in a flaſk almoſt to redneſs, to expel the water and any muriat of ammonia that it may contain; being then weighed it is to be ignited in a ſilver or platina crucible till the whole of the carbon is burnt off, and the reſidual iron is oxydized: from the weight of this oxyd is to be deducted 48 per cent. on account of the oxygen, and the difference between the weight of the remainder and that of the black powder before ignition indicates the amount of carbon.

The affinity of iron for carbon is pretty conſiderable, though it is by no means capable of decompoſing carbonic acid by combining with its baſe, as Muſhet has clearly ſhown in oppoſition to the aſſertion of Clouet.

The effects produced upon iron by carbon are very remarkable. Firſt with regard to colour: the bluiſh grey tint of iron becomes more and more white in proportion as it combines with carbon, till it poſſeſſes almoſt a ſilvery colour and luſtre, as is the caſe with the white caſt iron, in which ſtate the metal ſeems to be ſaturated with carbon. At the ſame time that theſe changes of colour are going on, the tendency to cryſtallization is rapidly increaſing, hence the fracture from being fibrous and hackly, becomes firſt compact, then granular, and at length exhibits facets like antimony. With theſe changes the fuſibility increaſes, and the faculty of welding diminiſhes, and ſoon entirely ceaſes: the ductility and malleability alſo undergo an analogous change, though not quite to ſo great an extent: the hardneſs increaſes, as alſo does the property of induration by ſudden cooling, and the capability of being tempered.

Iron however may not only be ſaturated but ſuperſaturated with carbon: that is to ſay, when at a very high temperature it will diſſolve more carbon than it can hold in ſolution at a lower temperature; and in conſequence, by ſlow cooling while it is ſtill fluid, a part of this exceſs of carbon will ſeparate from the reſt of the maſs and riſe to the ſurface, forming a flaky cruſt of plumbago or carburet of iron. Some however of the plumbago will ſtill remain inveloped by and diſperſed through the iron, giving it an uniform dark grey or black colour if the proportion is conſiderable, or only mottling it if the exceſs of this ſubſtance is very ſlight.

The actual proportions of carbon contained in the different kinds of iron have not yet been aſcertained with any accuracy either by analyſis or ſyntheſis; but thus much appears certain, that bar iron in general contains a ſmaller quantity than the ſofter varieties of ſteel, and theſe again always contain leſs carbon than the common and finer caſt ſteel; that in the white, the mottled, the grey, and the black varieties of caſt iron, the doſe of carbon is conſtantly augmenting, in the laſt of which the proportion of carbon is probably about $\frac{1}{10}$ of the whole.

Oxygen is alſo contained in moſt of the varieties of iron, and the effects occaſioned by it in the different proceſſes to which this metal is ſubjected, require more attention than has hitherto been paid to them. Caſt iron appears to be highly charged with oxygen, and on this account requires to be ſuperſaturated with carbon in order to be converted with any economy into bar iron. It may ſeem at firſt a paradox to maintain the coexiſtence of oxygen and carbon in the ſame metallic maſs, eſpecially conſidering the great heat to which it is expoſed in the proceſs of reduction, ſince it is an univerſal and uncontroverted fact that metallic oxyds are decompoſed by carbon at a high temperature, the oxygen and carbon uniting together and being diſſipated in the form of gas, the metallic regulus remaining behind. But when the roughneſs of the ſmelting proceſs in blaſt furnaces, and the large quantity of materials operated on at once, as well as the great preſſure of the ſuperincumbent ſcoriæ are taken into conſideration, we ſhall ceaſe to be ſurprized at the apparent anomaly. The exiſtence of oxygen in caſt iron, is manifeſt from the phenomena that accompany the operation of *puddling* as already deſcribed in a preceding ſection. The crude iron being ſubjected to a high temperature, under a preſſure no greater than that of the atmoſphere, the oxygen and carbon that it contains react upon each other and produce carbonic acid and gaſeous oxyd of carbon, which having eſcaped, the metal is found reduced to a ſtate of malleability. The ſame effects take place in cloſe veſſels, as Dr. Beddoes has well ſhown.[1] If

[1] Phil. Tranſ. lxxxii.

crude caſt iron is put into a retort, as ſoon as the veſſel and its contents have acquired a low red heat, an inflammable gas mixed with carbonic acid is given out with conſiderable rapidity (this inflammable gas muſt from the circumſtances be the oxyd of carbon) when the production of gas ceaſes, the iron upon examination will be found to have loſt ſomewhat of its weight, and to be nearly in the ſtate of bar iron. But though this combination of the oxygen and carbon of the crude metal, and the conſequent generation of air takes place with great eaſe when the beak of the retort is but juſt dipped under water, yet if the preſſure amounts to five inches of water, in addition to the atmoſphere, the diſengagement of air proceeds very ſlowly, and entirely ceaſes if inſtead of the water a ſingle half inch of mercury is employed; although upon removing this obſtacle the bubbles of air paſs through as before.

By the treatment that caſt iron undergoes during its converſion into malleable bar iron, the greater part of the oxygen and carbon is got rid of; ſtill however a ſmall quantity of oxygen, the ſmaller in proportion to the goodneſs of the iron, remains. This is inferred with much probability from the bliſtered appearance that the bars of iron exhibit after having been converted into ſteel by cementation. Theſe bliſters are manifeſtly occaſioned by the exudation of a gas from the bar, and this gas in all probability is oxyd of carbon. A further proof of the exiſtence both of oxygen and carbon even in Swediſh bar may be deduced from ſome intereſting experiments by Mr. Muſhet.[a] Having put ſome pieces of Swediſh bar iron into an earthen crucible, with a flux compoſed of marble and calcined clay, he obſerved firſt, that the earths melted together before the iron ſhowed ſigns of fuſion, and that while this latter was melting, bubbles of air were continually riſing from it and paſſing through the vitrefied flux: this gas burnt with a lambent blue flame, and probably was gaſſeous oxyd of carbon: the iron ſuſtained a notable loſs of weight, and had become conſiderably ſofter than at firſt.

Steel probably is entirely free from oxygen.

The action of vitreſcent earthy mixtures comes next to be conſidered. It is certain that caſt iron contains a very conſiderable proportion of ſcoriæ diffuſed through its ſubſtance, which are partly got rid of by ſubſequent fuſion, as they riſe to the ſurface of the metal being conſiderably lighter than it, while ſuch portions as ſtill remain are got rid of for the moſt part, by hammering and laminating during the converſion of the caſt iron into bar. A very ſmall proportion of ſcoriæ however is not unfrequently left in the iron, as is obvious from the earthy reſidue that ſome of the varieties of this metal leave behind them when diſſolved in acids. It is not yet clearly made out what is the preciſe effect of a little earth on the malleability of iron. Clouet has endeavoured to ſhow[b] that it renders the iron ſofter and more malleable, but inclined to be hot ſhort, and the experiment by which he demonſtrates it is the fuſing together of iron and glaſs, by which the effects juſt mentioned are produced upon the metal. But this is preciſely the ſame experiment as that of Mr. Muſhet's related in the preceding paragraph, and M. Clouet having entirely overlooked the extrication of gas from the metal, has gratuitouſly attributed the change produced to a combination of the iron with a little of the glaſs, without, as appears, taking the trouble to ſubſtantiate his hypotheſis by actual analyſis.

Caſt iron made with coak inſtead of charcoal muſt neceſſarily contain a variable proportion of ſulphur, nor is this ſubſtance very likely to be entirely diſſipated by the ſubſequent refining that the metal goes through; and it appears from a direct experiment by Dr. Beddoes, that iron after being puddled and ſtamped, if treated with muriatic or ſulphuric acid, will give out ſulphuretted hydrogen. Bergman has ſhewn that certain varieties of iron contain manganeſe, and others phoſphoric acid. Clouet has detected arſenic in ſome; and other chemiſts have ſomewhat obſcurely intimated the preſence of lead, copper, and zinc, which is far from improbable, as ſeveral of the ores of iron are occaſionally mixed with galena, copper pyrites and blende. But the effect of theſe ſubſtances in ſmall quantity on iron has not yet been aſcertained by any experiments that can be depended on; it is therefore obvious how much remains to be done before we acquire a thorough knowledge, even on practical points, of this moſt important of all metals.

The following, in the preſent ſtate of our reſearches on this ſubject, may be laid down as the eſſential characters of the principal forms under which iron exhibits itſelf. Crude caſt iron beſides caſual impurities contains carbon, oxyd of iron, and vitrefied earth. The difference between white, mottled, grey and black caſt iron depends on the proportion of carbon, which is ſmalleſt in the white and greateſt in the black. By the proceſs of refining or reſmelting, moſt

[a] Tilloch's Phil. Mag. xii. p. 102, 202.

[b] Journ des Mines, No. 49. p. 4.

of the earth and oxyd of iron rises to the surface of the metal in the form of a dense slag; hence the residual iron differs from the crude pig-metal in containing less earth and oxyd. By the subsequent operations the carburet and oxyd of iron mutually decompose each other, forming carbonic acid and carbonous oxyd, by which the metal is freed both from its oxygen and carbon. In this state it forms bar iron, which may or may not retain a small proportion of vitrefied earth, but which seems even when purest to hold a little both of carbon and oxyd. If this bar iron is exposed in a close vessel to a high heat, the carbon and oxygen that it contains (if they are in due proportion to each other) will be entirely got rid of, the metal will become very soft, and will be at the same time malleable and fusible. If the bar iron instead of being heated by itself has access to carbon either in the state of charcoal or plumbago, its oxygen will be expelled and carbon will at the same time be absorbed: if the portion of this latter is small, the mixture will partake of the properties both of iron and steel, hence it will be very malleable and capable of being welded, but also will be harder than pure iron, somewhat more fusible and susceptible of being tempered. By being united with a fresh portion of carbon it will become still more fusible and will lose its welding property; it will become harder, more compact, and will form the fine cast steel. A further portion of carbon increases the brittleness and hardness, so as to render it incapable of being wrought, and its colour and texture will approach to that of white cast iron: in this state it may be regarded as saturated with carbon. It is however capable of uniting to this substance even to supersaturation, by which its colour and texture resembles that of grey or black cast iron; its fusibility is somewhat increased, but its hardness is so much lowered by this excess of carbon as to allow it to be wrought with ease by a common file, nor can it be materially hardened by sudden cooling or be tempered, so that it is no longer in the state of steel. By a still further cementation with charcoal it would in all probability be converted into plumbago.

Many chemists have supposed that supercarbonized steel is the same thing as crude iron, because they resemble each other in their fracture and colour and contain carbon; and upon this reasoning have been founded several imperfect and ineffectual methods of applying the finer kinds of cast iron to some of the uses of common cast steel; but we have shown that however great may be the resemblance in some points, yet cast iron essentially differs from steel in containing both earth and oxyd of iron, and therefore cannot be substituted for it with any success.

It only remains to say a few words concerning two states of bar iron called *hot-short* and *cold-short*.

Iron that is hot-short or red-short is very soft and ductile when cold, on which account it is generally employed in the manufacture of wire; it may also be hammered and welded if treated skilfully at a full white heat, but when it has cooled down to a cherry red, it breaks away before the hammer and is dissipated almost like sand.

Cold-short iron on the contrary is harder not only than hot-short but also than pure Swedish bar iron; it may be wrought in the usual way when red or white hot, but possesses no toughness when cold; so that a large bar may with ease be broken across by a common hand hammer.

Hot-short iron is imagined, rather than proved, to contain arsenic, to which its brittleness at a red heat is supposed to be owing.

Cold-short iron is supposed by Bergman to derive its characteristic qualities from a portion of phosphoric acid; and it is certain that phosphat of iron has been found in iron of this description, both by the illustrious Swedish chemist just named and Meyer and Clouet.

If however it be granted that hot-short and cold-short iron respectively contain arsenic and phosphoric acid, yet it must in return be allowed that these qualities appear in very many cases where there is no reason to suspect either the one or the other, and that the methods by which these defects may be produced or remedied are in many cases at least not very reconcilable with their supposed origin.

If white cast iron, that is, such as is deficient in carbon, be exposed to the action of a current of flame after it has exhibited its proper degree of malleability, it will pass into the state of cold-short iron, and its brittleness will increase in proportion to the length of time that it is thus exposed.* Does it not therefore seem probable that in many cases at least the defects of cold-short iron are occasioned by an absorption of oxygen? This however the advocates for the universality of Bergman's theory on this subject may allow with perfect consistency. They would say that the phosphat of iron

* Musket in Phil. Mag. ii. p. 161.

originally contained in the ore is converted by the proceſs of ſmelting into phoſphuret of iron, which being capable of uniting perfectly with bar iron and forming only a very ſmall proportion of the whole, may render the iron hard without materially impairing its toughneſs while cold: but when this iron deprived of carbon is expoſed at a high temperature to the action of the air, the phoſphorus becomes acidified, and the phoſphat of iron that hence reſults being incapable of combining with malleable iron is merely diſperſed through it, and muſt therefore tend to render it brittle. Nor is the explanation of the fact contradicted by the methods made uſe of to correct this quality. Rinman ſays that caſt iron which by the common treatment would yield cold ſhort bar, may be made to afford ſoft malleable iron by fuſing it with a mixture of equal parts of lime and ſcoriæ. Mr. Muſhet[v] ſays that 875 grains of cold ſhort iron when melted by itſelf in a covered crucible formed a perfect button covered by a thin film of brown glaſs. The metal weighed only 805 grains, and inſtead of being cold-ſhort, was now found to have acquired the oppoſite fault of being hot-ſhort, it was extremely ſoft and ductile. In theſe experiments it may be ſaid that the metal being brought to a ſtate of quiet fuſion, the phoſphat of iron either entirely or at leaſt for the moſt part ſeparated in the form of glaſs from the reguline portion. But as all the above phenomena may be accounted for equally well upon the ſuppoſition that the cold-ſhort quality is owing ſimply to the mixture of oxyd of iron with the metal, it would be uſeleſs to ſpeculate further on the ſubject till a ſufficient number of accurate analyſes have been performed to direct our inveſtigations. The hot-ſhort quality appears to be occaſioned by the admixture of ſome ſubſtance which enters into fuſion at a low red heat, and thus deſtroys the tenacity of the iron through which it is diffuſed: hence this variety of iron cannot bear the hammer at a red heat, though when the temperature is raiſed to the full welding point, the effect of this unknown ſubſtance is counteracted by the tenacity which the particles of iron then acquire. This ſubſtance has been by ſome ſuppoſed to be carbon, but this is inconſiſtent with the extreme ſoftneſs which always characteriſes hot-ſhort iron: for the ſame reaſon it cannot be phoſphorus. The effects are more like thoſe of a metallic body; and lead, arſenic, copper, and zinc may be each ſuſpected with almoſt equal probability. In ſome varieties of hot-ſhort iron, eſpecially thoſe made with coak, the fragility increaſes with the increaſe of temperature, and they are wholly incapable of welding: this probably ariſes from a large admixture of the ſame ſubſtance, whatever it be, to which the more uſual characters of hot-ſhort iron are owing, with perhaps a little ſulphur.

§ 6. *Phyſical properties of Iron and Steel.*

Iron whether in the ſtates of caſt or bar iron, or ſteel, is attractable by the magnet, and capable of acquiring polarity, this laſt property however is more durable and powerful in ſteel than in any of the other forms of this metal.

Supercarbonized caſt iron is of a dark-grey almoſt black colour, has a granular fracture, is very brittle, is more fuſible than the other kinds of caſt iron, and yields without difficulty to the file. White caſt iron is of a tin-white colour, and a coarſe grained fracture; it is brittle but very hard, and leſs fuſible than the preceding variety. The grey and the mottled varieties approach nearer to the one or the other in proportion to their colour. The ſpecific gravity of caſt iron has not been aſcertained with great exactneſs, and no doubt is ſubject to ſome variations: that which is moſt highly carbonized has the leaſt ſpecific gravity, nor does it probably ever much exceed 7.01. Caſt iron takes impreſſions from moulds with much more ſharpneſs and preciſion than any other metal: and when in fuſion if pieces of caſt iron are thrown in, they will be obſerved to float on the ſurface till they melt and mix indiſtinguiſhably with the reſt; hence it has been generally acquieſced in that melted caſt iron is of greater ſpecific gravity than when ſolid; contrary to what takes place in all the other metals. This however ſeems to be founded on a mere fallacy, for if it were true, the iron when poured into a mould and beginning to ſolidify, ought to ſpirt out part of the melted metal, as water does under ſimilar circumſtances when converting into ice: whereas on the contrary, a conſiderable contraction happens which obliges the workmen who are employed in caſting large pieces, to fill the runners or channels into the mould with melted metal, leſt any cavities ſhould be formed in the piece and thus ſpoil it. Further, this contraction is ſo well known, that when caſtings of particular dimenſions are required, the mould is conſtantly made larger than the pattern by $\frac{1}{96}$ or ſometimes $\frac{1}{72}$, to allow for the ſhrinking. Now it is impoſſible that this ſhould happen if the ſpecific gravity of the melted metal really exceeded that of the ſolid metal: how then does

[v] Muſhet in Phil Mag. xii. p. 198.

it happen that the ſolid will float on the fluid metal? the anſwer to this is not perhaps very obvious; but it may be remarked that not only ſolid caſt iron but even bar iron which is of conſiderably greater ſpecific gravity, and not only bar iron but even lead which is more than half as heavy again as caſt iron, will float upon its ſurface. But though caſt iron like all other metals ſhrinks when it becomes ſolid, yet at the inſtant of congealing it appears to undergo a momentary expanſion, and thus takes a remarkably perfect impreſſion of any pattern with which it comes in contact.

Bar iron is of a blueiſh white colour, has a fibrous hackly fracture, is malleable both when hot and cold, and is capable of uniting with another piece of bar iron by welding: it may be drawn into very fine wire, and is the moſt tenacious of all metals, a wire $\frac{1}{10}$ of an inch in diameter being capable of ſuſtaining from 450 to 500 lbs. before it breaks. It is fuſible, but requires for this purpoſe a higher heat than caſt iron. Its ſpecific gravity is ſubject to ſome variations: that of common hammered iron, according to Dr. Pearſon, is from 7.45 to 7.6: Swediſh bar iron varies between 7.70 and 7.78. It expands like all other metals by heat: the amount of its expanſion for every degree of Fahrenheit's thermometer between the freezing and boiling point of water, is equal to 0.0000063 58.

Steel is of a light-grey colour and a fracture more or leſs fine granular: it is harder and more brittle than bar iron in proportion to the quantity of carbon that it contains; when ſlightly charged with this ſubſtance it is malleable, ductile, weldable and elaſtic, but when more nearly ſaturated with carbon it is not capable of being welded, and its fuſibility is increaſed. It may be hardened by ſudden cooling, and may afterwards be made ſofter by tempering. Its ſpecific gravity varies much: that of the beſt bliſtered ſteel before hammering is =7.81, of the ſame after hammering =7.73: of very hard ſteel =7.26; of melted ſteel wire =7.5; of Engliſh caſt ſteel hammered, from 7.82 to 7.91.

§ 7. *Chemical properties of Iron.*

Iron when heated very intenſely, that is, to about 155° to 160° of Wedgewood, melts, and if in contact with air, or only looſely covered with the burning coals, it takes fire and burns with uncommon beauty and brilliance, ſending forth moſt dazzling bluiſh white ſparks to a conſiderable diſtance, like fire-works. This is eaſily ſhewn by heating a piece of thick ſoft iron wire in the hotteſt part of a good blaſt furnace, and may conſtantly be obſerved in a blackſmith's forge at the inſtant that the horſeſhoe or any other piece of thin iron is withdrawn to be removed to the anvil. Thin iron conſumes very rapidly in this way, and falls down in a half-fuſed metallic ſlag.

The combuſtion of iron takes place very rapidly in oxygen gas, forming ſome beautiful experiments as firſt noticed by Dr. Ingenhouz. For this purpoſe fill a flaſk with oxygen gas, and having previouſly fitted a cork to it, thruſt a piece of thick iron wire through, juſt long enough to hang down to the middle of the flaſk, and round this thick wire make a ſpiral coil of thinner wire about the diameter of packthread. Faſten to the lower end of the ſpiral a very ſmall piece of lint, (previouſly ſoaked in nitre and dried), which ſet fire to, and immediately introduce the whole into the flaſk, thruſting it down as low as the cork will permit it. The flame of the lint ſoon communicates to the wire which kindles, and burns with great beauty, and a hiſſing noiſe, ſending off bright ſparks, and in proportion as the flame travels up the ſpiral coil, drops of melted and oxydated iron fall down, while hot, and penetrate the ſubſtance of the glaſs, unleſs ſome water is left at the bottom.

This experiment is performed with rather more effect in jars open at top and bottom, the top opening being much ſmaller and fitted with a perforated cork. The melted drops then do not crack the glaſs veſſel as in the former caſe.

Another method of burning iron in oxygen, firſt adopted by Dr. Prieſtley, is by throwing the heat of a powerful lens on iron confined in a glaſs jar of this gas. *Caſt* iron was found to burn much more vehemently than hammered iron, for the former as ſoon as any portion was melted gathered into a round ball, diſperſing into a thouſand directions like a moſt beautiful fire-work, and attended with a hiſſing noiſe.

Iron is alſo readily burnt by a powerful galvanic pile, and with the ſame beautiful appearance.

The reſult of this combuſtion, however performed, is a black, brittle, ſhining, magnetic oxyd.

There are alſo many other ways of oxydating iron, as this metal has a very great tendency to abſorb oxygen and carbonic acid either from the air or from any ſurrounding ſubſtance capable of ſupplying oxygen, particularly water in any form.

Hammered iron if kept at a low red-heat very ſoon becomes rough at the ſurface, and

peels off into thin ſcales (as every one muſt daily obſerve in the iron work about common fires and pokers) which alſo are the metal oxydated to a low degree, and therefore ſtill magnetic.

The common ruſt which collects upon hammered iron by expoſure to air and moiſture, and which in time corrodes the thickeſt bars, is not the ſimple oxyd, but a *carbonated* oxyd, or a compound of iron, oxygen, carbonic acid, and water, and is not of itſelf magnetic unleſs mixed with fragments of the iron detached by the ruſting.

Water affords another means of oxidating iron, and ſeveral curious circumſtances attend this change. When the ſteam of water is preſſed over iron kept red hot, the water is decompoſed very rapidly, its oxygen paſſing to the iron, and its hydrogen appearing alone in the form of *Hydrogen Gas*, (as mentioned under that article). The ſame change however will take place even at the common temperature of the air, but the oxyd will then be in the form of a black powder, and will not exhibit that gloſſy appearance which it does in the former method. The preparation called *martial ethiops* is iron oxidated by water, and was firſt made by Lemery the younger, in the following way: take any quantity of clean iron filings, put them in any veſſel and cover them with water to about three or four fingers breadth, let them remain for a conſiderable time (and ſpeedier if kept in a warm place) frequently ſtirring them up and ſupplying the waſte with freſh water, ſo as to keep the iron covered. After a while bubbles of hydrogen conſtantly riſe from the maſs, and the veſſel becomes full of a very fine black powder which may be ſeparated from the remainder of the filings by being ground up with water and poured off before it has ſubſided. Let it then ſettle, dry it ſlowly, and keep it in a well-cloſed bottle.

This black powder is iron in the firſt or loweſt ſtate of oxydation, or *ſub-oxyd;* it is ſtrongly magnetic, but has a conſtant tendency to abſorb an additional quantity of oxygen from the air or any other ſubſtance, by which it loſes its magnetic property, changes from black to yellow or red, and acquires very different chemical characters. From the experiments of Prouſt and other chemiſts, it appears that theſe two ſtates of oxydation of iron are very conſtant and uniform, that is to ſay, that iron has properly only two diſtinct modes of combination with oxygen, namely as the *black magnetic ſub-oxyd*, which is compoſed of about 27 of oxygen and 73 of iron; and the *perfect oxyd* the colour of which is more or leſs of a red, and is compoſed of about 48 of oxygen and 52 of iron. It ſeems probable that there is no proper intermediate degree of oxydation except what may be produced by mere *mechanical* mixture of various proportions of theſe two oxyds; but as ſoon as any portion of the ſub-oxyd is in a ſtate to abſorb oxygen at all, it amounts to the proportion of 48 in 100 before a ſecond portion begins to change: and vice verſa when the perfect oxyd is reduced to the ſub-oxyd.

The preparation of the black ethiops in Lemery's method is tedious, and many attempts have been made to ſhorten it. The difficulty is to arreſt the oxygenation of the iron at the point in which it remains as a ſub-oxyd, for the tendency which it has to full oxygenation is very ſtrong. This is much aſſiſted by heat, and it is found that the ethiops when expoſed to air in any conſiderable quantity, heats ſpontaneouſly, and rapidly ſaturates itſelf with oxygen. On this ſubject Van Mons[a] relates the following curious experiment: having collected a quantity of the black ſub-oxyd, he put it while wet into a retort and heated it there to drive off the ſuperfluous water, and at the ſame time to guard againſt the free admiſſion of external air. When taken out the oxyd was of a very fine black, but as ſoon as expoſed to the open air, a ſpontaneous motion or heaving took place through the maſs, it became ſo hot as to burn a thick double paper in contact with it, and the whole in a few minutes was converted into the red or perfect oxyd, or *Saffron of Mars*.

Hence the ſub-oxyd ſhould be dried only in ſmall quantities and very gradually.

Roover's proceſs,[b] which is a ſlight alteration and improvement of Lemery's, is to take iron filings, not freſh, but half ruſted by expoſure to air, moiſten them thoroughly with water and let them remain twenty-four hours. This produces much black oxyd, which ſhould be ſeparated by grinding and decantation as uſual, and a freſh affuſion of water will then produce another quantity of black oxyd, which may be repeated as long as required. The oxyd is then boiled for a minute with water in an iron veſſel, and afterwards dried with precaution. It is then very pure and good. The oxydation of the metal is much aſſiſted if the water employed be ſlightly acidulated with muriatic acid.

[a] Journ. de Pharmacie, p. 151.

The ſulphat or muriat of iron precipitated by ammonia alſo affords a ſub-oxyd generally magnetic, which will be further mentioned.

Another method of preparing this ethiops is by diſoxygenating the perfect oxyd. For this purpoſe put any quantity in a crucible, make it fully red hot, project on it a little linſeed oil or white wax, cover the crucible, and continue the heat till the contents have ceaſed to ſmoke. The carbonaceous matter here takes away all the exceſs of oxygen, and what remains is the black magnetic ſub-oxyd or ethiops.

Another ingenious method propoſed by Vauquelin of obtaining the black ethiops is by heating ſtrongly for two hours, given proportions of the red oxyd and iron filings. The oxygen then becomes nearly equally divided throughout the whole maſs, ſo that the red oxyd becomes changed to the black by loſing oxygen which the iron filings gain in their converſion to the ſame.

To convert the whole into an ethiops ſimilar to that prepared in any other way, (that is of which 100 parts contain 27 of oxygen) it will be neceſſary therefore to take $1\frac{1}{2}$ part of the red oxyd at 48 per cent. of oxygen, and 1 part of iron filings, that is to ſay, ſuppoſing no loſs of oxygen, but that the whole becomes equally diſtributed in the maſs. After all however it is ſtill doubtful whether a perfect chemical mixture of the two ingredients can be obtained in this way.

The red perfect oxyd above mentioned is alſo called *Saffron of Mars*, or *Crocus Martis*, and is uſed both medicinally and as a poliſhing powder. It is the ſtate in which iron is contained in many of its acid ſolutions, particularly the nitric, as will be preſently mentioned. It is alſo produced by the calcination of the black ethiops with a red-heat in an open veſſel and with frequent ſtirring.

None of the oxyds of iron are ſoluble in pure water. The oxyd ſcarcely melts by itſelf in the ſtrongeſt heat, but is a powerful flux for all earthy mixtures. It parts with a portion of its oxygen by a very intenſe heat, and at a low red heat when in contact with carbonaceous matter. It gives to earthy and vitreſcent mixtures various ſhades of red, yellow, and green, according to circumſtances. (See the article *Glaſs.*)

Iron in the metallic ſtate is ſoluble in water impregnated with carbonic acid. This carbonat is the form in which iron is found in by far the greater number of mineral chalybeate waters. Thus an artificial chalybeate water imitating that of Tunbridge (for example) may be made ſimply by putting a few iron filings in a bottle filled with carbonated water, and letting it remain ſome hours with frequent ſhaking. This fact was firſt obſerved by Mr. Lane.[a] If this ſolution be expoſed to the air, it quickly exhibits on the ſurface an irideſcent film conſiſting of the oxyd of iron beginning to ſeparate. By reſt the whole of the iron is depoſited as a yellowiſh-red oxyd, which according to Bergman[b] amounts to about $\frac{1}{100}$ of the weight of the water, that is, when the latter originally contains about its own bulk of carbonic acid. This oxyd is at firſt magnetic, but ſoon loſes this property, owing to a further abſorption of oxygen. The pure alkalies ſeparate this oxyd from the water but not the carbonated alkalies, hence in many mineral waters, carbonated ſoda and carbonated iron are found together. It is owing to the ſpontaneous ſeparation of the oxyd by expoſure to air that the channels and reſervoirs in which the natural chalybeate waters flow are always lined with a red ochre.

The *oxyds* of iron are not ſoluble in carbonated water, when as Bergman has obſerved, the carbonic acid has been procured from the calcination of lime or magneſia, that is to ſay, when it is pure; but when from effervеſcing ſubſtances by means of the ſtronger acids, ſome of the oxyd will be diſſolved—a convincing proof that ſome portion, though extremely minute, of the diſplacing acid is carried up with the carbonic acid gas, though too ſmall to be detected by common teſts.

Carbonated iron is readily and totally ſeparated from the water by a boiling heat for a few minutes, which affords an eaſy method in chemical analyſis. When carbonat of lime is alſo contained, moſt of it ſeparates along with the iron. Heating the water will alſo diſcover whether the iron it contains is held diſſolved by the carbonic or by a fixed acid; if by the former, the water will not ſtrike a purple with galls, if by the latter, this change takes place as eaſily as before.

A ſingular circumſtance has been remarked with regard to ſome of the hot chalybeate waters, ſuch as thoſe of Bath or Carlſbad, which is, that though when quite freſh and hot from the ſpring, they give a very decided chalybeate taſte, and a ſlight but unqueſtionable purpling with galls, and blue with pruſſiat of potaſh;

[a] Phil. Tranſ.

[b] Eſſays on the Aerial acid.

both the taſte and the power of theſe teſts are loſt as ſoon as the water cools, before any perceptible depoſition of oxyd takes place, and even if the water be incloſed while hot in a well corked bottle, which it quite fills, and therefore without any obvious loſs of carbonic acid. In theſe caſes however there is always a ſlight ochery depoſit on the ſides of the bottle which cannot be reſtored by heating again, though with the veſſel ſtill cloſed. It is not eaſy to explain this circumſtance, nor is it quite decided whether in theſe caſes, the ſolvent of the iron is really the carbonic acid. It may be added that when the quantity of iron is extremely minute the moſt certain way of applying the gall nut teſt is to ſuſpend with a ſtring a ſmall piece of the nut in the bottle, and then to fill it with the water at the ſpring head, and let it remain well corked for ſome time.

The ſulphuric acid diſſolves iron, and forms the well known ſalt *Sulphat of iron*, *Green vitriol*, *Green copperas*, or *Sal martis*. The greater quantity of this ſalt which is uſed in manufactures of various kinds, particularly in dyeing black, is not prepared from the direct combination of its ingredients, but from various kinds of native ſulphats of iron or pyrites (deſcribed in § 1 of this article) after they have undergone ſpontaneous oxygenation by long expoſure to air. Green vitriol is prepared in many counties in England; the firſt manufacture of the kind was undertaken in the reign of queen Elizabeth, at Deptford, where it is ſtill carried on.[e] It is likewiſe made largely in Northumberland and Durham. The method of manufacture is ſimple, and ſcarcely differs now from what it was more than a century ago as deſcribed by Colwall.[d]

The following is the proceſs actually in uſe.[e]

"The uſual mode of manufacturing copperas "on the rivers Tyre and Wear, is by expoſing "iron pyrites (there called *braſſes*) which are "found in the collieries, to the influence of the "atmoſphere. For this purpoſe a ſituation is "choſen inclining towards the river, of a natu- "ral ſtrong clay. After the ſoil is taken off, "gutters are cut in different directions, and "wells of about 5 or 6 feet deep, and 2 or 3 "in diameter, are ſunk where the gutters ter- "minate. Upon this ſurface the *braſſes* are "laid to the thickneſs of 4 or 5 feet. The "vitriolization ſhews itſelf in a white efflores- "cence, which is waſhed off by the rain into "the gutters and conveyed by pipes from the "wells to a reſervoir, from which there is a "pipe of communication to the boiler. This is "a leaden veſſel generally about 7 feet deep, "12 to fourteen long, and 6 or 7 wide, where "the liquor is evaporated for 6 days, during "which time a quantity of old iron is added to "it, as much as it will diſſolve. It is then run "into a cryſtallizing veſſel, and remains there "for five weeks, at the end of which time the "mother liquor is run into a reſervoir, and "pumped back into the boiler, and the cryſtals "are removed, and after being well drained "are packed in hogſheads for ſale. A ſingle "boiling from a boiler of the above dimenſions "yields from 5 to 8 tons of copperas, accord- "ing to the ſtrength of the liquor."

Vitriol is made near Haguenau on the Rhine nearly in the ſame manner, according to the deſcription given by Cavillier.[f] The pyrites is diſpoſed on an inclined ſoil in beds about two feet thick, beneath which are gutters going to a common reſervoir. The vitriolization of pyrites is always ſeen by whitiſh efflorescences taſting ſtrongly of vitriol, at the ſame time that the ſurface of the pyrites cracks in every direction. When the ſeaſon is dry it is occaſionally watered to carry off the vitriol already formed, and to promote a freſh vitriolization in the remaining ore. The heaps are found to be exhauſted when theſe ſaline efflorescences are but ſcanty, and when the lump when broken appears changed throughout into the *liver pyrites*.

The vitriolic liquor is evaporated as uſual in lead boilers, but it does not appear that old iron is regularly added to ſaturate the liquor as in England, but only occaſionally when it appears too acid. Some of the mother liquor of the former operation is always added.

The evaporated liquor before it paſſes into the cryſtallizing pools is ſent to another baſon, where it remains for twenty-four hours to depoſit a large quantity of ochre. The cryſtallizing pools are made of fir planks ſurrounded with beaten clay. It requires ten days for the ſolution to depoſit all its cryſtals, part of which is collected on ſticks put into the veſſel, but the pureſt vitriol is depoſited the laſt. The liquor that remains after the depoſition of the cryſtals (or the *mother-water* as ſuch liquors are always termed) is reſerved, and a portion is always added to the boiler in the next evaporation.

The vitriolization of the common pyrites uſed in theſe manufactures is a work of conſiderable time, more or leſs according to cir-

[c] Watſon's Eſſays. [d] Phil. Tranſ. vol. xii. [e] Original communication. [f] Journ. des Mines, No. 36.

cumſtances, but it is generally ſeveral months before a bed is entirely exhauſted. Vitriol is however alſo made in ſeveral places from *vitriolic peat*, and in this the proceſs is much ſhorter. A large manufactory of vitriol from this ſource is carried on near Beauvais in France,[g] thus deſcribed by M. Briſſon.

The peat in the neighbourhood is of two kinds, the common combuſtible peat and the vitriolic. The former is, as in other countries, light, ſpongy, and full of viſible remains of leaves, ſtalks, and vegetable fibres. The vitriolic on the other hand is eaſily diſtinguiſhed by being heavier, harſher, and crumbly. The waters that run from it alſo depoſit much ochre which readily detects the ſituation. The vitriolic peat is not found uniformly in any relative ſituation with the other ſpecies, but at different depths from the ſurface to about ten feet.

This peat is hardly expoſed to the air before it opens of itſelf and becomes very dry and harſh, and ſoon heats even in ſmall maſſes. To render the vitriolization more uniform and prevent the too drying effect of the ſun, the peat is laid in heaps only three or four inches in thickneſs under ſheds thatched with ſtraw, where they remain for a few days, after which they are ready for lixiviation. This is done by throwing the peat into large vats of maſonry and covering it with rain water, which flows through the heaps and is collected for the purpoſe, and alſo with ſome of the mother water of the former cryſtallization. It is then evaporated and cryſtallized in the method already deſcribed.

In ſome places the pyrites requires roaſting before it can be decompoſed by the action of the air. Thus at Geyer in Saxony[h] the pyrites, after being expoſed for ſome time to the air, is ſoaked in water for twelve hours, then roaſted as in the ordinary method of roaſting ores, in a large bed upon faggots, on which about ſeventy or eighty quintals at a time are heated red-hot, and in this ſtate plunged again into water. This is repeated ſix times ſucceſſively with the ſame pyrites, by which the water becomes ſtrongly impregnated with vitriol and is afterwards evaporated and cryſtallized as uſual.

A quantity of heat is always generated during the proceſs of vitriolization, both in the firſt combination of iron with ſulphur and the ſubſequent oxygenation of the ſulphur, and conſequent converſion into ſulphuric acid, which enables it to diſſolve the iron and form the ſulphat required.

The degree of the heat produced, and the quantity of moiſture which the pyrites receives (by rain or other ſources) are the circumſtances that principally regulate the production of vitriol, both as to quantity and time of its production. Too much heat actually kindles the maſs; the remaining ſulphur takes fire, and an immenſe quantity of ſulphureous acid vapour is given off to a great diſtance around. Where this takes place little or no vitriol is produced, for moſt of the ſulphur and acid already formed is diſſipated, and alſo the iron becomes too much oxydated to yield the cryſtallizable ſalt. Hence it is dangerous and prejudicial to make too large heaps of pyrites or to put it up into ſtacks however preſerved from the weather. Some moiſture is alſo neceſſary to vitriolization, but too much of it keeps the pyrites too cold and the proceſs is languid. The iron added during the boiling is certainly uſeful, both as ſaturating the acid and encreaſing thereby the yield of the ſalt, and alſo as precipitating by its ſuperior affinity any copper which may ariſe from the admixture of copper pyrites, and alſo undergo vitriolization. In ſome manufactures however the admixture of a ſmall portion of ſulphat of copper is even an advantage, as in the dyeing of hats.

Since the method of preparing the ſulphuric acid from ſulphur and nitre has been univerſally adopted, a part of the uſe of vitriol of iron (namely for the production of ſulphuric acid) has paſſed away, but it is ſtill employed largely in the preparation of nitric acid in many places beſides its extenſive uſe in dyeing.

Sulphat of iron is alſo made even in the large way in London, by the direct combination of iron and ſulphuric acid, which is found to anſwer on the whole in point of cheapneſs, as a purer ſalt is obtained, and at an incomparably ſhorter time. Moſt of the ſalt of this kind uſed in medicine is prepared in this way.

Iron is not ſoluble in the *concentrated* ſulphuric acid when cold, but if heat is applied the acid is partially decompoſed, ſulphureous acid gas is given out, and the oxygen of the decompoſed acid paſſes to the metal, and ſulphat of iron is formed with the remaining acid. But when the acid is diluted the ſolution goes on rapidly even in the cold, much hydrogen gas is given out by the decompoſed water, and ſulphat of iron is formed in abundance. Some

[g] Journ. de Phyſ. tom. 4.

[h] Jars Voyages Metal. tom. 3.

heat is generated in the process. The process often becomes languid or altogether stops when the quantity of water is comparatively small, owing to the salt crystallizing round the iron and encrusting it so as to prevent the acid from reaching it. A little heat is then useful to redissolve the salt and saturate the acid thoroughly.

All the common sulphat of iron, especially that prepared in the great way from pyrites is a mixture of two distinct salts, the nature of which was first fully shewn by Proust, and which it is necessary to be aware of to understand the chemical changes that take place with this salt in different circumstances. The first of these is the *green sulphat of iron*, or that salt which gives the common sulphat its leading external characters, and of which it forms by far the largest portion when fresh made, before it has been exposed to the air.

The green sulphat is a very beautiful salt, when regularly crystallized forming rhomboid prisms, of a cold sea-green colour, with a strong styptic taste and sensibly acid so as to redden litmus. It is soluble in twice its weight of water at 55°, but in less than its own weight of boiling water.[i] It is insoluble in alcohol. It does *not* give a black colour with galls, and with the prussiated alkalies it gives a *white* and not a blue precipitate. These two important facts discovered by Proust very strikingly distinguish it from the common sulphat of iron. The pure green sulphat when decomposed by the alkalies gives a very light green precipitate, but which speedily grows yellow by contact with air. This salt is obtained by agitating the common green sulphat with sulphuretted hydrogen gas.

This salt as well as the common sulphat recently made, though of a pale clear green at first, soon becomes covered with a yellow ochre when exposed to the air. When the solution in water is also kept in half-closed bottles it soon grows turbid, deposits a reddish-yellow oxyd of iron, which gradually increases in quantity, and at last the whole or nearly the whole remaining liquor is changed into a red fluid, much more astringent in its taste than before, and if evaporated contains hardly any crystallizable salt, but leaves a red deliquescent mass intensely styptic. This saline substance is the *red sulphat of iron* which differs from the green sulphat in many essential characters, being uncrystallizable by common means, soluble in alcohol, giving an immediate black with galls in any form, and a deep blue with the prussiats.

It appears from the experiments of Proust and others that these two salts differ from each other chiefly in the proportion of oxygen united to the iron in solution, the oxyd of iron of the green sulphat being composed of about 27 per cent. of oxygen and 73 of iron, and the oxyd of the red sulphat containing the metal at its highest state of oxygenation, that is at 48 of oxygen to 52 of iron, as already mentioned in describing the oxyds.

The green sulphat having a constant tendency to absorb oxygen, and thus to be converted into the red sulphat, most of the changes which each salt undergoes may be explained from this circumstance.

Scheele was aware that the precipitation of the red oxyd from the common green sulphat depended on the action of the atmospheric air, for he gives it as a test to discover this air contained in water, to put a small crystal of the purest green vitriol in a phial perfectly full of the water, to be examined, and to cork it closely; when as he observes, it will be found that in a day's time a quantity of ochre sediment will fall to the bottom, which will not take place if a similar experiment be made with distilled water recently boiled to purge it of all its air. The change from the green to the red sulphat also takes place more speedily by the addition of the nitric or oxymuriatic acid to the former salt, these furnishing the requisite quantity of oxygen. On the other hand the red is converted to the green sulphat by *disoxygenating* processes, that is, either by the contact of sulphuretted hydrogen in any form, or by adding some metallic tin, zinc or mercury, according to Proust, all of which produce this partial disoxygenation. When the red sulphat is boiled on metallic iron, as happens when the mother-water in vitriol-making is returned to the boiler, some oxyd of iron is precipitated, and part of the remaining liquor is changed to the green sulphat and crystallizes on cooling. Hence the economy of using up the mother-liquor with fresh iron, as above-mentioned. Possibly sulphuretted hydrogen might be used in vitriol-making with advantage.

The red sulphat is precipitated by the pure alkalies of a deep red colour, differing much in this from the other salt, which gives a light pea-green precipitated with the same. Ammo-

[i] Beaumé.

nia partially reduces the perfect oxyd if dried in a close veſſel, and brings it to the black or magnetic ſtate.

Some intereſting experiments have been made by Mr. Davy[k] on the abſorption of nitrous gas by green ſulphat of iron, a combination which is found to be very valuable in EUDIOMETRY. The fact of the abſorption was firſt noticed by Dr. Prieſtley. A pure red ſulphat of iron was made by paſſing oxymuriatic gas through a ſolution of common green vitriol, till it gave only a red precipitate with potaſh. Nitrous gas being thrown up to a quantity of this ſolution, the colour changed to a muddy green, but the abſorption was very trifling.

On the other hand a pure green ſulphat was formed by diſſolving iron filings in dilute ſulphuric acid, agitating the ſolution in contact with ſulphuretted hydrogen, and then boiling it. This gave a white precipitate only with pruſſiat of potaſh, and therefore was unmixed with any of the red ſulphat. Nitrous gas being agitated with this ſolution, it ſoon became of an olive-brown, and a quantity of the gas equal to four times the bulk of the ſolution was abſorbed. As long as the ſolution remains cold the nitrous gas does not ſeem to undergo any alteration; but when heat is applied a part of it is given out unchanged, but a part diſappears, and at the ſame time a quantity of red oxyd of iron is precipitated, and ſome ammonia is found in the ſolution. No nitric acid is formed in the proceſs, and hence the author of the experiments infers that the nitrous gas is decompoſed, its oxygen paſſing to the iron, and producing the red oxyd, and its azot entering into the compoſition of the ammonia; and to account for the hydrogen, the other conſtituent of the ammonia, recourſe is had to the ſuppoſition of a concomitant decompoſition of water, whoſe oxygen alſo aſſiſts in the full oxygenation of the iron.

The green ſulphat of iron, according to Kirwan contains in 100 parts, 28 of black or ſub-oxyd of iron (at 27 in 100 of oxygenation) 26 of real ſulphuric acid, and 46 of water, of which he eſtimates 38 to be water of cryſtallization and the remaining 8 to be water of compoſition.

Green vitriol when heated melts in its own water of cryſtallization. When all this is driven off by a boiling heat, there remains a grey maſs commonly called calcined vitriol. The ſalt has loſt only water by this firſt proceſs, as is proved by performing it in a retort and collecting the liquor driven off by the heat. It was formerly called *dew of vitriol*, and ſeveral fanciful alchemical properties were aſcribed to it. If the calcined vitriol be urged in a ſtrong heat, and confined in a porcelain or luted glaſs retort, ſulphureous acid gas mixed with ſulphuric acid comes over and continues to do ſo for a conſiderable time, till the ſalt has been for ſome time fully red-hot. What remains is a blood-red maſs, conſiſting of a perfect oxyd of iron with a ſmall portion of ſtill undecompoſed ſulphat of iron, which being now in the ſtate of the red ſulphat is deliqueſcent, and cauſes the maſs to grow damp by expoſure to air. This red maſs is called *colcothar*, and is much uſed for poliſhing metals, glaſs, &c. but is previouſly waſhed in warm water to extract every thing ſaline that remains. If colcothar is further urged with a very intenſe white heat, a large quantity of oxygen gas is given out, and an oxyd of iron is left, which is ſlightly magnetic, and therefore in the ſtate of a ſub-oxyd. Therefore the decompoſition of the ſulphuric acid firſt affords a quantity of oxygen to unite with the iron naturally in the ſtate of ſub-oxyd in the ſalt, and a very intenſe heat again drives off this additional oxygen, and leaves the iron nearly as at firſt. Along with the ſulphureous gas that is given out ſo abundantly in diſtilling green vitriol, a quantity of a very ſtrong ſmoking and peculiar ſulphuric acid comes over, which concretes in the receiver in long ſtriated rays or cryſtals. This acid from the place of its firſt production was called *ſmoking vitriolic acid of Nordhauſen*. It is now found to be ſulphuric acid ſaturated with ſulphureous acid gas, to which it owes its concreſcibility. (See SULPHURIC *Acid.*)

The red ſulphat of iron is generally conſidered as uncryſtallizable, and to differ ſtrikingly in this reſpect from the green ſulphat, but Mr. Hauſſman[l] gives ſeveral examples of cryſtals being formed in this ſolution which appear to be this ſulphat of iron in the higheſt ſtate of oxygenation. This accurate chemiſt relates that on mixing together a pound of nitrat of iron and half a pound of concentrated ſulphuric acid, and evaporating the whole to dryneſs in a porcelain diſh, a white inſipid reſiduum remained, which on being left to itſelf for ſome weeks had deliqueſced and acquired an aſtringent taſte. The deliqueſced liquid being then poured off and kept in a glaſs, gradually depoſited beautiful colourleſs tranſparent

[k] Reſearches.

cryſtals reſembling alum, which immediately gave a blue precipitate when added to pruſſiat of potaſh. Theſe cryſtals had an intenſely aſtringent taſte, became yellowiſh in the air, and when diſſolved in water and heated depoſited a yellow oxyd.

The ſame chemiſt alſo obtained cryſtals of this ſulphated oxyd of iron by diſſolving the perfect oxyd procured from the nitrated iron by potaſh in ſulphuric acid, and adding an exceſs of the acid.

Alſo, when common ſulphat of iron ſaturated with nitrous gas or mixed with nitric acid is ſimply evaporated to the conſiſtence of honey, no cryſtals are formed, but on adding about a ſixth of ſulphuric acid, the whole becomes a confuſed cryſtalline maſs.

Theſe experiments would ſeem to ſhew that this ſulphated oxyd of iron requires a greater exceſs of acid to cryſtallize than the ſulphated ſub-oxyd or green ſulphat, but this opinion does not correſpond with the fact that in the gradual converſion of the green to the red ſulphat by expoſure to air and heat, a large quantity of inſoluble oxyd is precipitated, ſo that the common ſolution of uncryſtallizable red ſulphat that is left muſt contain even more acid proportionally to the iron than the cryſtallized green ſulphat.

Further experiments on this ſubject are ſtill wanting.

The action of the ſulphureous acid upon iron has been inveſtigated by Berthollet, and afterwards by Fourcroy[g] and Vauquelin. When liquid ſulphureous acid is poured upon iron filings it immediately becomes of a deep buff colour, ſome hydrogen gas is given out, much heat is excited, and the colour ſoon changes to green. With other acids the ſolution then gives out ſulphureous acid gas, and at the ſame time lets fall a white powder which is true ſulphur. A large quantity of the acids is required for this. The nitrous acid ſeparates the ſulphur as a ductile maſs.

The ſolution of iron in the ſulphureous acid, or the *ſulphite* of iron, depoſits a reddiſh-yellow cryſtalline powder, of which when waſhed in water the ſaline part diſſolves, and a reſidue is left which is ſulphur holding a little iron. This ſaline part is a ſimple ſulphite of iron, or one in which there is no exceſs of ſulphur, and when expoſed to the air it gradually paſſes to the ſtate of ſulphat as takes place with the alkaline ſulphites. The ſulphite of iron does not give a black with galls nor a blue with the pruſſiated alkalies, and hence it is probable that the iron is in its loweſt ſtate of oxygenation.

Nitric acid diſſolves iron with extreme vehemence when a little diluted with water, for when quite concentrated it does not act on iron any more than on tin. The action of this acid on iron is attended with copious red fumes, conſiſting chiefly of nitrous gas and nitrous oxyd. At the ſame time much yellowiſh-red oxyd of iron ſeparates, ſo that the ſolution is ſenſibly acid. When much concentrated it often ſuddenly takes a gelatinous form. The ſolution at firſt is of a light green, but when nearly ſaturated aſſumes a deep-red colour. When the action of the acid is very powerful, ammonia is formed, as is ſhewn by adding lime to the ſolution, which immediately gives an ammoniacal ſmell. This nitrat of iron is not cryſtallizable, when evaporated to dryneſs it leaves only a red viſcid maſs very deliqueſcent. It gives a ſtrong blue with the pruſſiats and a black with galls, and appears to contain the iron therefore in its higheſt ſtate of oxygenation. It has little if any power of abſorbing nitrous gas.

There is another ſtate of nitrat of iron which may be called *nitrated ſub-oxyd of iron*, and is procured by digeſting ſlowly and without heat a very dilute nitric acid upon iron, not in very ſmall diviſions, or elſe by adding lumps of iron to the common ſolution. In the latter caſe much of the perfect oxyd falls down, and the metallic iron appears to take its place. This ſolution of iron in very weak acid gives out, while forming, but very little gas for ſome time,[h] and becomes dark-olive brown. When neutralized by the alkalies it gives a light green precipitate. With galls however it gives a black, and with the pruſſiats a green precipitate, ſo that it appears to be a mixture of the two ſpecies of nitrats. In this ſtate it will abſorb much nitrous gas. When heated it paſſes to the ſtate of the firſt-mentioned nitrat.

Nitric acid will not diſſolve iron much oxygenated, and therefore in chemical analyſis boiling to dryneſs a ſmall quantity of nitric acid off any oxyd of iron is often uſed to bring it to an uniform ſtate of oxygenation (in this caſe the higheſt) by which its proportion of metal may be fairly eſtimated. A hundred parts of this oxyd therefore, when fully dried, are equivalent to 52 of metal and 48 of oxygen, as already repeatedly mentioned.

When the nitrat of iron is decompoſed by carbonated potaſh an exceſs of the alkali re-diſ-

[g] Syſteme de Con. Chem.

[h] Davy, Reſearches.

ſolves the precipitate, as will be preſently noticed.

The oxymuriatic acid oxydates and diſſolves iron. The oxyds of iron are diſſolved by it with difficulty, but if a quantity of the carbonated oxyd or ruſt be diffuſed in water, and oxymuriatic acid gas paſſed through it, or, more ſimply, if the ruſt a little wetted be put on a flat diſh, and expoſed to the vapour of this acid, a ſolution is effected, and a brown liquor of a very ſtyptic taſte is produced, but which has not been much examined.

Muriatic acid diſſolves iron and its oxyd with great eaſe, more ſo than any other acid, and ſeveral intereſting combinations are produced thereby.

When this acid is poured on iron filings a great quantity of hydrogen gas of a very peculiarly fœtid ſmell is given out, and a ſolution is effected, which is of a pale-green if kept excluded from air. This is generally turbid at firſt with a number of black ſpecks, which are the carburet of iron that this metal almoſt always contains, and is inſoluble in the acid. This ſolution gives a white precipitate with pruſſiated alkali, and a light-green oxyd with the pure alkalies. It has a ſtrongly ſtyptic acid taſte. By evaporation from a veſſel with a ſmall orifice, ſo as to exclude the air as much as poſſible, it gives greeniſh-white cryſtals, inſoluble in alcohol, but very ſoluble in water.[i]

A ſimilar variety takes place in the muriated as in the ſulphated iron, that is, there are two very diſtinct ſalts, the one already mentioned being the green muriat or muriated *ſub-oxyd* of iron, and which by abſorption of oxygen readily changes to the red muriat, or that in which the iron is completely oxygenated.

The green muriat alters much leſs by ſimple expoſure to air without heat than the green ſulphat, but in time the colour of the ſolution reddens, and ſome red oxyd of iron ſeparates. The ſame takes place more ſpeedily when the ſolution is heated, or when a few drops of nitric or oxymuriatic acid are added. This red muriat of iron is alſo formed directly by adding muriatic acid to the perfect oxyd of this metal. It differs from the other both in colour and in taſte, being much more aſtringent, and in not being cryſtallizable, for when evaporated nearly to dryneſs it only leaves a dark orange-coloured ſaline magma, ſoluble in alcohol. This ſolution is uſed in medicine. With the alkalies it gives a red precipitate, and with the pruſſiated alkalies a very deep blue.

The ſame phenomena take place with regard to the mutual converſion of the green and red muriat into each other as with the green and red ſulphat, ſulphuretted hydrogen changing the red to the green muriat, and oxymuriatic or nitric acid changing the green to the red. The green muriat alſo abſorbs nitrous gas even more rapidly than the ſulphat, and to double the extent, giving a very dark-brown ſolution. The red muriat on the other hand abſorbs ſcarcely a particle of the gas.

If concentrated muriatic acid is heated upon red oxyd of iron a little oxymuriatic acid gas is given out.

Muriatic acid when heated, always carries off with it, as it evaporates, a ſmall portion of iron, and to this is to be attributed the colour of common muriatic acid when made in the large way. If the ſaline maſs, that remains when common muriat of iron is evaporated nearly to dryneſs, be further heated in a retort, a liquid muriat of iron ſublimes, which on cooling, concretes into ſmall yellow needled cryſtals on the ſides of the receiver. If the remaining maſs be further urged with a full red heat, a ſub-muriated oxyd of iron ſublimes which cryſtallizes in ſix-ſided plates.[j] The cryſtallized muriat is ſoluble in alcohol, and is the baſis of ſome empiric medicines.

The acetous acid diſſolves iron and its ſub-oxyd, forming a brown-red ſolution not cryſtallizable. It has not been much examined. An impure acetite is uſed very largely in *Dyeing* and *Calico printing*. It is made chiefly of ſour beer and other ſubſtances that have undergone the acetous fermentation, and lately of the pyromucous acid ariſing from the diſtillation of charcoal for the manufacture of gunpowder.

Mr. Hauſſman in his memoir on the formation of ammonia[k] gives a method of preparing the acetited oxyd of iron highly oxygenized by adding to ſulphat of iron diſſolved in dilute nitric acid, or elſe ſaturated with nitrous gas, a ſolution of acetited lead, ſulphat of lead falls down, and the ſolution contains the acetited oxyd of iron. Acetited iron may alſo be made more ſimply and elegantly by adding acetited potaſh to its weight of common ſulphat of iron, rubbing them together, which makes a deliqueſcent maſs, and then adding warm alcohol to the mixture. An acetited iron is made by double decompoſition, which alone is diſſolved in the alcohol, the ſulphat of potaſh being left. This alcoholic ſolution is uſed ſometimes in medicine, and is the Tinctura Ferri Acetati of

[i] Davy. [j] Fourcroy. [k] Journ. de Phyſ. tom 30.

the Dublin Pharmacopœia. By gentle heat the alcohol evaporates and the acetited iron is left.

The phoſphoric acid acts upon iron but ſlowly. The native phoſphat, and its effect on the texture and manufacture of iron have been already deſcribed. The phoſphat of iron is in its common ſtate a ſalt inſoluble in water. The obſervations of Fourcroy and Vauquelin on this ſalt are intereſting. Vauquelin found it to compoſe the greater part of the brittle ſcales which rapidly form on the ſurface of iron, and corrode it through in no very great length of time, when expoſed to be perpetually moiſtened with urine. Theſe ſcales are much more bulky than the iron which furniſhes them, are very brittle, full of knobs, and when examined cloſely, their fracture preſents a gloſſy ſpathoſe ſemi-cryſtalline texture. Heated in a crucible they melted without difficulty, and gave an uniform grey metallic button of a very hard and cloſe grain, which was phoſphat of iron, and covered with a greeniſh porous ſcoria of phoſphat of lime holding oxyd of iron.

Phoſphat of iron is alſo prepared by adding a ſolution of phoſphat of potaſh or of ſoda to the ſulphat, nitrat, or muriat of iron. A white precipitate of phoſphat of iron is formed by double decompoſition, which like many of the other phoſphats is ſoluble entire in many of the acids, and precipitable thence by ammonia without alteration.

In examining the nature of the colouring matter of BLOOD,[l] the ſame chemiſts diſcovered another ſpecies of phoſphat of iron, namely with exceſs of baſe, or what amounts to the ſame, with a deficiency of acid, and which therefore may be termed a *ſub-phoſphat of iron*. If the calcined reſidue of blood, after all the volatile parts have been driven off by heat gradually increaſed to redneſs, be treated with weak nitric or muriatic acid, a portion is diſſolved, the reſidue being left redder than before. The ſolution ſaturated with ammonia depoſits a grey precipitate, which is the common phoſphat of iron. This transferred when ſtill wet into cauſtic potaſh partly diſſolves into a deep blood red liquor. The potaſh here firſt deprives the phoſphat of iron of a portion of its phoſphoric acid but not the whole, and the remainder is ſub-phoſphat of iron, which by diſſolving in the alkaline liquor gives it the deep red colour, ſo that the ſolution appears to be compoſed of phoſphat of potaſh, ſub-phoſphat of iron, and a large exceſs of pure potaſh. They alſo find that this ſub-phoſphat of iron diſſolves readily and without heat in liquid albumen, as the white of an egg beat up with water, and alſo in the ſerum of blood, (both of which contain uncombined ſoda) and give them a deep red colour. An additional quantity of alkali heightens the colour.

The ſuccinic acid forms with iron a brown ſaline maſs inſoluble in water. The affinity of this acid for iron appears to be very ſtrong, and its inſolubility perfect, and hence it has been propoſed lately by M. Gehlen as a very uſeful and diſcriminating teſt for this metal held in ſolution by any other acid. The ſuccinic acid however before it can be uſed in this way, ſhould be ſaturated with an alkali, generally ſoda, and the ſolution to which the ſuccinat of ſoda is applied ſhould alſo be previouſly neutralized with the ſame alkali, but ſo as not to render it cloudy. The ſulphat, nitrat, muriat, and other known ſolutions of iron are then decompoſed by the affuſion of the ſuccinat of ſoda or ammonia, and a looſe brown-red precipitate of ſuccinat of iron falls down. Profeſſor Klaproth in uſing this teſt[m] collects the precipitate, ignites it by itſelf in a covered crucible, which gives ſome ſmall blue flame, owing to the deſtruction of the ſuccinic acid; rubs the calcined reſidue with a very little linſeed oil, and again ignites it in a covered crucible, which reduces the iron to the black magnetic ſub-oxyd.

The firſt calcination of the precipitate leaves the iron in the ſame ſtate, ſo that the treatment with linſeed oil is only a meaſure of precaution.

Dr. Marcet however has found in his analyſis of the Buxton chalybeate water,[n] that the ſuccinat of ammonia is not ſo excluſively a precipitant of iron as has been ſuppoſed, as it will equally ſeparate alumine from its ſolutions, but not the other earths.

The oxalic acid readily diſſolves iron with effervescence, forming a ſweet aſtringent ſolution;[o] when made without heat it yields priſmatic cryſtals of a greeniſh yellow colour, with exceſs of acid and very ſoluble in water. When calcined there remain 45 parts from 100, which are red oxyd of iron. The oxyd of iron is ſoluble in this acid, but with difficulty.

Tartareous acid diſſolves iron with effervescence and diſengagement of hydrogen, and forms a red gelatinous maſs which does not cryſtallize. When this acid is poured into a ſolution of ſulphat of iron no precipitate is at

[l] Syſteme de Conn. Chim. tom 9. [m] Analyſis of Gadolinite. Eſſays, vol. 2.
[n] Saunders on Mineral Waters, ſecond edition. [o] Bergman on Acid of Sugar.

firſt formed, but on heating the mixture, according to Retzius,[p] the acid unites with the portion of oxyd which is naturally ſeparated from the ſulphat by heat, and lamellar cryſtals of tartrited oxyd of iron are depoſited.

Cream of tartar, or the ſuper-tartrite of potaſh alſo diſſolves iron with eaſe, and this combination is well known in medicine. The tartariſed iron is prepared by mixing together one pound of iron filings with two pounds of cream of tartar, and moiſtening it with a pint of water and expoſing it to the air for a week, then gently evaporating the mixture to dryneſs. This gives a brown powder conſiſting of cream of tartar and oxyd of iron. But a more perfect mixture is formed by boiling together 8 ounces of cream of tartar, with 2 of iron filings in about 6 pints of water. The cream of tartar diſſolves in the water with part of the iron, and on cooling, the clear liquor depoſits cryſtals, which are therefore tartrite of potaſh and iron. A further evaporation yields more of theſe cryſtals. This maſs remaining after the cryſtals have depoſited, is ſoluble in alcohol, and forms the *Tartarized Tincture of Iron*.

Some other varieties of theſe preparations are employed which need not be enumerated.

It is however a property peculiar to the tartareous acid to render iron ſoluble in cauſtic alkali, or to prevent the precipitation of iron from its ſolution in other acids even by a large exceſs of alkali, which without the preſence of the tartareous acid would be immediately depoſited. So Klaproth in his analyſis of umber,[r] added to the muriat of iron, produced by digeſting umber in muriatic acid, ſome tartrite of potaſh, (ſoluble tartar) and afterwards ſuperſaturated the whole with cauſtic ſoda, but no turbidneſs was produced, but only a clear brown-red liquor. Cauſtic ammonia had the ſame effect. This red liquor was therefore a compound of oxyd of iron, tartareous acid, potaſh, ſoda, and muriatic acid, and (in this caſe alſo) oxyd of manganeſe.

The combination of the gallic acid with iron has been already repeatedly mentioned in this article, and alſo under INK and GALLIC ACID, (which ſee.)

The diſcovery is due to Prouſt of the circumſtance that the *ſub-oxyd* of iron, either as a ſulphat or a muriat is not precipitated by galls, nor in any degree blackened, hence it is doubtful whether when gallic acid is added to a ſalt of this ſpecies any decompoſition is effected, or whether a gallat of iron is really produced, but colourleſs, and ſoluble in the remaining liquor. But the ſalts with the perfect oxyd are immediately decompoſed by the gallic acid, and the well known black inky precipitate ſlowly ſeparates. This precipitate of black gallat of iron is light and bulky ſo as to ſubſide extremely ſlowly, and ſcarcely at all when the liquor is thickened by mucilage, as in common ink.

The pruſſic acid forms with oxyd of iron one of the moſt important combinations, and one which has more engaged the attention of chemiſts than any other of the ferruginous ſalts. It will be deſcribed under the article *Pruſſiat*, (which ſee). As with the gallic acid, an equal difference takes place in the combination of pruſſic acid with iron according to the degree of oxygenation, alſo diſcovered by Prouſt. With the ſub-oxyd, the precipitate is white, and with the perfect oxyd, blue.

The ſalts produced by the combination of the *Arſenic* acid with iron have already been mentioned in this article under the method of analyſing the natural arſeniat of iron.

It appears probable that all the acid ſalts of iron are capable of theſe two modifications, ſo often mentioned, depending on the different ſtate of oxygenation of the metal; that is, according to Prouſt, where the metal forms 73 per cent of the oxyd, and where it forms only 52.

The alkalies when cauſtic have no power of diſſolving iron. The fixed alkalies precipitate it from its acid ſolutions apparently in the ſame ſtate of oxygenation in which it exiſted in the ſolution: but as the ſub-oxyd has always a ſtrong tendency to abſorb oxygen from the air, and as this action is particularly aſſiſted by heat and moiſture, it generally happens that the precipitate in the uſual courſe of proceeding, eſpecially when heat is uſed, is in the ſtate of the perfect oxyd by the time it is thoroughly edulcorated and dried.

But ammonia, on account of its ready decompoſition by moſt metallic oxyds, and the diſoxygenating property of the hydrogen diſengaged in the proceſs, when uſed as a precipitant of the ſalts of iron leaves the metal in the ſtate of ſub-oxyd when dried without much acceſs of air, and will deoxidate the red oxyd when digeſted with it in a ſtopped bottle, at the ſame time that bubbles of azotic gas are diſengaged.[s]

The effect of the tartareous acid in rendering iron ſoluble in the alkalies has been already mentioned.

[p] Fourcroy ſyſtem. tom. 7. [q] Pharm. Lond. [r] Eſſays, vol. 2. [s] Fourcroy.

The carbonated alkalies on the other hand diſſolve the oxyd of iron with eaſe. This ſolution was firſt noticed by Stahl, and is called after this eminent chemiſt the *Alkaline Tincture of Iron*. This preparation was originally made by adding to nitrat of iron the *oil of tartar per deliquium*, or common carbonat of potaſh deliqueſced in the air. The firſt effect is to precipitate a red oxyd from the ſolution: but when the alkali becomes in exceſs, the oxyd is rediſſolved and forms a blood-red liquor. The deliquiated carbonated potaſh is really preferable to a ſolution of the ſalt made directly, as this alkali during expoſure to air abſorbs carbonic acid rapidly, and the power of diſſolving the oxyd of iron depends on the proportion of carbonic acid united with the alkali. Hence the cryſtallized carbonat of potaſh is ſtill better for this purpoſe. The carbonats of ſoda and ammonia are equally powerful in diſſolving the precipitated oxyd, and not only the nitrat, but any other ſalt of iron will ſucceed.

Theſe ſolutions are all decompoſed by expoſure to air, eſpecially aſſiſted by heat, owing to the eſcape of the carbonic acid. They are alſo decompoſed both by the ſtronger acids, and by the alkalies in a cauſtic ſtate, the former act by ſaturating the exceſs of carbonated alkali and driving off the carbonic acid, the latter ſimply by abſorbing ſo much carbonic acid that the quantity contained in the whole ſolution is not ſufficient to hold the oxyd of iron diſſolved. The *Alkaline Tincture* decompoſed by nitric acid added gradually ſo as not to paſs the point of ſaturation, depoſits the red oxyd of iron which made in this manner was called *Stahl's Aperitive Saffron of Mars*. An exceſs of the acid rediſſolves the precipitated oxyd.

Many of the neutral ſalts act powerfully on iron, forming combinations, ſome of which have been noticed by chemiſts.

If one part of clean iron filings be rubbed with two or three parts of nitre, and the mixture thrown by ſpoonfuls into a clear crucible made fully red-hot, the mixture burns with great brilliance, throwing out numerous bright ſparks that have a very ſtriking effect. This combination is uſed in ſome fire-works. After the deflagration is over there remains a half-fuſed maſs conſiſting of the iron reduced to the ſtate of red oxyd and diffuſed but not diſſolved in a ſaline maſs ſtrongly deliqueſcent. This ſalt is the alkali of the nitre in a cauſtic ſtate. If warm water is poured on the maſs, the alkali readily diſſolves, leaving a red oxyd of iron in a pulverulent ſtate. This oxyd is *Zwelfer's Saffron of Mars*. If the iron is more than will engage all the acid of the nitre, ſome of it will remain metallic, if the nitre be in exceſs, the lixiviated ſaline ſolution will contain ſome undecompoſed nitre together with the cauſtic potaſh.

Iron readily decompoſes muriat of ammonia when *aſſiſted by heat*, though on the other hand ammonia precipitates the muriat of iron. When equal parts of iron filings and ſal-ammoniac are intimately mixed together and heated, the decompoſition is very conſiderable, much of the muriatic acid unites with the iron, much of the ammonia flies off in the form of gas, or, if the experiment be made with a retort and receiver, part of the volatile alkali condenſes with the water of the ſalt in the receiver. But a portion of the ſal-ammoniac eſcapes decompoſition and ſublimes at a ſufficient heat in its uſual form. But as muriat of iron is alſo partly volatile when heated, ſome of this latter alſo riſes in intimate combination with the volatilized muriat of ammonia, and the ſalt that concretes is therefore a mixture of the muriats of ammonia and iron, but generally with the former in much greater proportion. The iron alſo muſt be oxydated before it can become ſoluble in the muriatic acid, and this is doubtleſs effected by the previous decompoſition of the water of cryſtallization of the ſal ammoniac, and hydrogen gas is actually found mixed with the ammoniacal gas during the ſublimation.

This ſalt is much uſed in medicine, and is called *Martial Flowers* or *Ferrum Ammoniacale*. As the object in the preparation of it is to decompoſe the muriated ammonia as little as poſſible, only a ſmall quantity of iron ſhould be uſed, the leaſt proportions being about 16 parts of muriated ammonia and one of iron filings. Theſe are mixed together and put into a ſubliming veſſel, and a heat applied gradually increaſed to redneſs. Some ammoniacal and hydrogen gaſſes are given out, and a quantity of cryſtallized martial flowers is found concreted at the upper part. This ſalt is of a reddiſh yellow, and ſomewhat deliqueſcent, both which properties are owing to the preſence of muriated iron. When the quantity of iron filings is increaſed, more ammonia is given out, and of courſe leſs of the ſublimed ſalt is yielded, but on account of the greater proportion of muriat of iron produced, the ſublimed ſalt is redder and more deliqueſcent. The proportions of iron and ſal-ammoniac preſcribed in the London pharmacopœia are one of the former and two of the latter. It is an inconvenience of this pre-

paration that it is not of itſelf uniform in the doſe of iron, as the quantity of muriat of iron which riſes in the ſublimation, is conſtantly increaſing. This inequality is remedied by mixing the firſt entire ſublimate with the reſidue and again ſubliming, and afterwards mixing the whole ſublimed ſalt uniformly by triture.

Iron when oxydated decompoſes muriat of ammonia more eaſily than when in the reguline ſtate, and the martial flowers are ſometimes made by mixing equal weights of the red oxyd and muriated ammonia, and ſubliming.[t] Much ammoniacal gas eſcapes, but part alſo of the muriat of ammonia riſes undecompoſed, and mixed with the muriat of iron in the form of the martial flowers.

In both theſe proceſſes a maſs of muriat of iron remains in the bottom of the ſubliming veſſel after the ſublimation is finiſhed.

Iron unites to ſulphur with great eaſe and in ſeveral proportions. The ſulphuret of iron is commonly made by melting together equal parts of ſulphur and iron filings in a covered crucible, with a moderate red heat, which proves ſufficient for perfect fuſion, and the reſult is a metallic, ſhining, grey-black maſs, very hard and brittle. Another and ſtill ſimpler method is to make a piece of thick iron wire or any other bar iron white hot, to take it out of the fire and immediately preſs a roll of ſulphur upon the heated parts, whereby the two will inſtantly combine and fall in drops of black ſulphuret into water placed beneath.

When the ſulphur and iron filings are heated together, as ſoon as they become red hot the combination takes place with ſudden rapidity, and the evolution of great heat and flame, even without the acceſs of external air. The like happens when iron filings are heated red hot in a retort or cloſe veſſel, and ſulphur dropped upon them, an incandeſcence immediately takes place, as was remarked by the antient chemiſts, and the black ſulphuret is produced. The black oxyd will alſo combine with ſulphur when heated with it in a cloſe veſſel, but with much more difficulty than metallic iron does.

Sulphur and iron filings will alſo chemically unite, and during their combination give out much heat. If equal parts of the two be well mixed, and moiſtened with water to a paſty conſiſtence, and expoſed to the air, the maſs ſoon heats, ſwells, cracks in every direction, evolves ſulphuretted hydrogen, and if the maſs be about five or ſix pounds of each ingredient, the gas takes fire, as during the vitriolization of pyrites.

[t] Pharm. Edin.

This actual combuſtion appears to have been firſt obſerved by Lemery the elder, who attributed the exploſion of volcanoes to this cauſe, and ſucceeded in forming ſomething like a volcano in miniature, by burying a large quantity of the materials a foot or two under ground. Beaumé deſcribes the phenomena of this combination with his uſual accuracy, and upon a very large quantity.[u]

One hundred pounds of iron filings and as much ſulphur in powder were mixed, moiſtened, and put into an iron pot. About ſix hours after, a ſmall quantity of water oozed out from the maſs, which had a vitriolic taſte; in five hours the mixture ſwelled and cracked in every direction, and began to heat, and ſend forth an aqueous vapour, which gradually increaſed during ten hours more, when the whole ſteamed ſo ſtrongly that the pot could hardly be diſtinguiſhed, and the vapour then acquired a very ſtrong fetid ſmell of ſulphur; after which it took fire and burnt with a flame about a foot in height for two or three minutes, and gave out a ſulphureous ſmell, leaving the maſs glowing hot, which continued to burn with frequent ſparkling for forty hours longer. In this operation the principal part of the phenomena muſt be aſcribed to the decompoſition of water by the ſulphuret of iron, as ſoon as formed, whence the production of the hydrogen holding part of the ſulphur in ſolution: the oxygen of the water unites partly to the iron and partly to the ſulphur, ſo that the ſeveral products are ſulphuretted hydrogen, ſulphuret of iron, and finally ſulphat or ſulphite of iron, which again, if the heat be very ſtrong, is in its turn decompoſed, as in the calcination of common green vitriol, and at laſt only a red oxyd of iron is left. The mixture of iron filings and ſulphur appears to begin its oxygenation by abſorbing this principle from the air, whence it forms a very good eudiometer, as deſcribed under that article; and by this the diſtinct exiſtence of the oxygen of the atmoſphere was firſt diſcovered by the illuſtrious Scheele; for the abſorption of atmoſpheric oxygen from any confined portion of air by this mixture takes place before the evolution of hydrogen. If the quantity of materials be ſmall, and the heat produced be only moderate, the reſidue after all mutual action has ceaſed, is a black ſulphuret of iron, capable of yielding much ſulphuretted hydrogen with acids, and mixed with ſome ſulphat of iron that may be ſeparated by lixiviation.

It has been a queſtion in what ſtate the iron

[u] Chym. Exper. tom. 2.

exists in the perfect sulphuret made artificially by fusion as well as in the natural pyrites. By the valuable researches of Prof. Proust,[v] corroborated by those of Mr. Hatchett,[w] it appears to be satisfactorily determined, that the iron is absolutely or very nearly in the metallic state, or in other words, that the sulphuret of whatever kind is composed simply of iron and sulphur.

Another important fact also ascertained by Proust is the existence of two very distinct species of sulphurets, the one with a larger, the other with a smaller proportion of sulphur, the latter of which may therefore be termed for the present the *sub-sulphuret*, and the former the *super-sulphuret*. This distinction is confirmed, and some other valuable observations are added by Mr. Hatchett in the paper above quoted. The distinction particularly applies with accuracy to the natural sulphurets, of which the different varieties of common unmagnetic pyrites are the sulphurets with excess of sulphur; and the magnetic pyrites described by Mr. Hatchett is the natural sub-sulphuret as already mentioned when treating of the ores of iron. The artificial compounds too in some degree follow the same tendency to unite with determinate doses of sulphur, possessing respectively peculiar chemical properties, but with less accuracy than the natural, since indeterminate degrees of sulphuration of iron may be artificially procured.

Several of the experiments of the two eminent chemists here mentioned deserve particular notice. It may be premised that the great chemical difference between the two species is that the super-sulphuret (the common pyrites when natural) is not magnetical, is nearly insoluble in muriatic or sulphuric acid, and especially gives no sulphuretted hydrogen by the action of these acids; whereas the sub-sulphuret (the magnetic pyrites when native) is obedient to the magnet, and readily dissolves in these acids, with copious evolution of very pure sulphuretted hydrogen. Both the natural and artificial sub-sulphuret may be converted to the super-sulphuret by an additional dose of sulphur; and vice versa, the super-sulphuret changed to the sub-sulphuret by taking away the excess of sulphur.

Prof. Proust gives the following experiments: a mixture of iron filings and sulphur (at random quantities) was heated moderately in a retort, to procure the black sulphuret for the use of the laboratory, to obtain sulphuretted hydrogen gas. This appearing to be not sufficiently charged with sulphur, was heated again with a fresh quantity, keeping the crucible in a red heat, but not equal to the fusion of the materials. But on treating the sulphuret thus obtained with an acid, he was surprised to find no sulphuretted hydrogen given out. Comparing this circumstance with the well known fact that common pyrites gives no gas with acids, nor is soluble in them till it is partially desulphuretted by roasting, it appeared obvious that there existed at least two distinct states of sulphuration in the artificial as well as the natural pyrites, with separate chemical properties.

Some natural pyrites which had been deprived of about 20 per cent. of sulphur by previous heating in a close retort, so as to exclude the air, and had become thereby soluble in acids and of a black colour, was then mixed with a large and indeterminate quantity of sulphur and exposed to a moderate heat in a retort by the side of another retort filled with some of the same pyrites in its natural state. The use of this last was to serve as a thermometer to regulate the heat, which was kept just below the point at which pyrites yields its excess of sulphur. The contents of the first retort first parted with a quantity of sulphur, but after this had ceased, nothing further was given out during an hour longer of heating, in all which time the natural pyrites underwent no change. The roasted pyrites was found after this to have acquired again rather more sulphur than it had lost, and had resumed its greenish yellow hue, but it still remained pulverulent. It *now* gave only a very small quantity of sulphuretted hydrogen by immersion in sulphuric acid, and remained insoluble in it though heated to boiling. Therefore, in every thing but in the crystallized form, the sulphuret had returned compleatly to the state of the natural pyrites, some slight differences excepted, which always must attend the laboratory attempts to imitate nature.

The sub-sulphuret and super-sulphuret were also made entirely artificially by first heating in a retort to full redness 200 grains of iron filings with sulphur till all the excess was volatilized, which left 318 grains of the black or sub-sulphuret, being an increase of 59 of sulphur in 100 of iron; and then heating this sulphuret with another dose of sulphur, (using a separate vessel of natural pyrites as a thermometer, as in the former case) which gave 378 grains, and was in the state of super-sulphuret or in chemical properties resembling the common pyrites.

[v] Jour. de Phyf. tom. 53 and 54.

[w] Phil. Tranf. for 1804.

From the above experiments therefore it appears that iron may be combined artificially with at leaſt two very diſtinct doſes of ſulphur, or rather, that there are two diſtinct points of extreme ſulphuration of iron, *according to the temperature uſed*. The firſt is iron united with the utmoſt quantity of ſulphur which it will retain in a cloſe veſſel when heated fully to redneſs, or to that degree in which the common pyrites loſes about 20 per cent of its ſulphur. This gives the black ſub-ſulphuret, ſoluble in acids with evolution of ſulphuretted hydrogen. The ſecond point is when iron already ſub-ſulphuretted, is heated with more ſulphur at a temperature juſt below the former, or ſuch in which common pyrites loſes none of its ſulphur, and the product of this is the ſuper-ſulphuret of iron, inſoluble or nearly ſo in acids, and giving no gas.

Theſe two ſulphurets ſeem to be the only ones hitherto found in nature, the ſuper-ſulphuret being the common pyrites, and the ſub-ſulphuret the magnetical pyrites, but in artificial combinations a great many intermediate degrees of ſulphuration may be effected. Thus a lower degree than is ever found native is that in which a little ſulphur is dropped upon red-hot iron filings, exciting a vivid combuſtion even in cloſe veſſels as already mentioned, and in which, according to Prouſt, 100 parts of iron acquire only from 20 to 30 of ſulphur. There are beſides intermediate ſtates of ſulphuration between the ſub-ſulphuret and the ſuper-ſulphuret as fully aſcertained by the valuable experiments of Mr. Hatchett.

Profeſſor Prouſt gives the following proportions of the two ſulphurets, namely, in the *ſub-ſulphuret*, (meaning the artificial, this chemiſt not being then acquainted with the compoſition of the magnetical pyrites) 100 parts of iron abſorb about 60 of ſulphur, ſo that 100 of the ſub-ſulphuret contain 62.5 of iron and 37.5 of ſulphur: and in the *ſuper-ſulphuret*, natural or artificial, 100 parts of iron abſorb 90 of ſulphur, ſo that 100 parts contain 52.64 of iron and 47.36 of ſulphur. Theſe proportions however appear from Mr. Hatchett's experiments to be not quite accurate.

The ſub-ſulphuret may alſo be conveniently prepared, according to Prouſt, by half-filling a crucible with common pyrites, covering it with a third or half its weight of iron filings, and over this a little charcoal-powder, and heating the whole red-hot for about a quarter of an hour. The heat need not be urged to fuſion of the materials. Or the pyrites and iron filings may be previouſly mixed. This gives a black brittle pulverulent ſub-ſulphuret which is the moſt convenient ſubſtance for the uſe of the laboratory for obtaining ſulphuretted hydrogen gas.

Mr. Hatchett in his analyſis of the natural ſub-ſulphuret of iron or magnetical pyrites, found it to agree in compoſition and all eſſential chemical characters with the artificial ſub-ſulphuret examined by Profeſſor Prouſt, and to be compoſed of about 37 of ſulphur and 64 of iron. But the compoſition of the natural ſuper-ſulphuret, or common pyrites, Mr. H. finds on the average of five experiments made on ſpecimens, the moſt diſſimilar in external appearance, to be 53.24 of ſulphur and 46.76 of iron, whereas Prouſt eſtimates it at only 47.36 of ſulphur and 52.64 of iron. As in Mr. Hatchett's analyſis the difference between the higheſt and loweſt quantity of ſulphur in all the ſpecimens did not amount to more than 2.19, it is probable that this diſagreement depends chiefly on the mode of analyſis, which being conducted in the moiſt way by Mr. H. we muſt conſider as by much the moſt accurate. Mr. H. alſo obtained an intermediate ſulphuret between the two ſpecies by diſtilling ſome of the magnetical pyrites with thrice its weight of ſulphur in a retort, with a heat gradually raiſed to redneſs. This produced a greeniſh-yellow pulverulent maſs, in which the ſulphur was about 46 per cent. or 9 per cent. more than in the magnetical pyrites, and which gave no ſulphuretted hydrogen with muriatic acid, though it partially diſſolved therein.

The circumſtances in which the ſulphurets of iron are affected by the magnet, as ſhewn by Mr. Hatchett in this memoir, are very remarkable.

In all ſtates of ſulphuration the iron appears to be in the metallic ſtate, and therefore of itſelf magnetic, but whilſt the ſub-ſulphuret of 37 per cent. of ſulphur is ſtrongly magnetical, the common pyrites and the artificial ſuper-ſulphuret (of 52 per cent. of ſulphur) are not in the ſmalleſt degree ſo, unleſs mixed with interſperſed iron, to which alone the magnetic property is owing.

Sulphur therefore in a certain proportion deprives reguline iron of the magnetical property, and the exact point of ſulphuration at which this ceaſes is not aſcertained, but Mr. H. found this property ſtill retained in the above-mentioned intermediate ſulphuret of 46

per cent. of ſulphur, and therefore it is loſt ſomewhere between 46 and 52 per cent. of ſulphuration.

The alkaline ſulphurets have little if any action on iron but diſſolve its oxyd, and acquire thereby an intenſe green colour, which the affuſion of an acid immediately deſtroys.

Sulphuretted hydrogen added either in gas or in a liquid form to any ſolution of iron, firſt deoxygenates it entirely or partially, and then forms a black precipitate of hydro-ſulphuret of iron. This precipitate is however reſoluble in moſt acids, or may be prevented from forming by previouſly acidulating the ſolution, in which reſpect it differs from the hydro-ſulphuret of lead; and hence in examining wines and other liquors ſuppoſed to contain lead, this metal is prevented from being confounded with iron, by uſing an acid along with a ſulphuret, under which circumſtances the lead will give a precipitate but the iron none. *(See Lead.)*

On account of the de-oxygenating property of ſulphuretted hydrogen in any form, with regard to iron, it always happens that the acid ſolutions of this metal that contain or are in contact with ſulphuretted hydrogen paſs to the ſtate of *ſub-oxydated* ſalts, the red ſulphat for example changing to the green ſulphat, the red muriat to the pale muriat, and the like. Alſo if a little of the perfect or red oxyd of iron be thrown into a bottle of ſulphuretted hydrogenous water, and well ſhaken, the ſmell of ſulphur is ſpeedily overcome, and the oxyd becomes black and more voluminous than before, and if collected and thrown upon a red-hot iron it gives out a ſtrong ſulphureous ſmell and blue flame, and if treated with muriatic acid it gives out ſulphuretted hydrogen.[a] In this experiment therefore the ſulphuretted hydrogen is decompoſed, the hydrogen appearing to be employed in partially deoxygenating the oxyd, and the ſulphur afterwards uniting with it into a hydro-ſulphuretted ſub-oxyd of iron.

Iron readily unites with phoſphorus, forming the phoſphuret of iron. This may be prepared according to Pelletier in two ways, either by the direct union of iron and phoſphorus, or by a mixture of phoſphoric acid, charcoal, and iron. In the latter method this ingenious chemiſt mixed one ounce of vitreous phoſphoric acid, one ounce of iron turnings, and a dram of charcoal, and melted them with a full heat for ſome time in a covered crucible, and the reſult was a harſh white granular button, partly cryſtallized in rhomboidal priſms, which was phoſphuret of iron mixed with ſome phoſphat. Another method adopted was to add ſulphat of iron in ſolution to human urine, which gave a precipitate of phoſphat of iron. An ounce and a half of this precipitate, mixed with two drams of charcoal powder, two drams of calcined borax, and as much glaſs, and melted in a ſtrong heat, gave a button of phoſphuret of iron weighing two drams. This phoſphuret put on a muffle in the midſt of the coals, ſoon melted, and on the ſurface ſmall jets of phoſphoric flame were ſeen, owing to the phoſphorus burning off. An ochery porous maſs remained. Iron may alſo be combined with phoſphorus, according to the ſame chemiſt, ſimply by mixing equal parts of vitreous phoſphoric acid and iron. In this proceſs a portion of the phoſphoric acid yields its oxygen to a portion of the iron, and the phoſphorus reſulting thence unites with that part of the iron which is left metallic, and ſettles at the bottom of the crucible as phoſphuret of iron, whilſt the remaining phoſphoric acid and oxyd form a black vitriform ſcoria on the ſurface.

The ſame chemiſt alſo projected ſmall pieces of phoſphorus on red-hot iron filings, which both together immediately melted down into a very hard white ſtriated button of phoſphuret of iron that was ſtill magnetical. The ſurface was covered with a black vitreſcent ſcoria, moſt of which ſoon run through the crucible.

The phoſphuret of iron thus produced contained about 20 per cent. of phoſphorus.

Iron when metallic is not ſenſibly affected by *oils* or any oleaginous ſubſtances, but on the contrary, theſe when freſh preſerve iron from ruſting by expoſure to air. But when the oils grow rancid the iron itſelf oxydates from this cauſe. A compoſition of hog's lard and a little camphor thickened with black-lead is ſaid to preſerve iron from ruſting better than moſt other greaſy compoſitions.

The oxyds of iron diſſolve in oils, giving them a reddiſh-brown colour. A very intimate combination of oil and oxyd of iron is produced by adding a ſolution of ſoap to a ſolution of ſulphat or any other ſalt of iron. This ſoon hardens to a very ſtiff paſty maſs.

The alloys of iron actually employed in the arts are very few, but this metal will combine more or leſs eaſily with moſt of the other metals. The amalgamation with mercury has generally been thought impracticable, but they may be made to combine by a method that will be mentioned under that metal.

[a] Fourcroy. [a] Memoires, tom. 1 & 2.

The few obſervations to be made on the different alloys of iron will all be deſcribed under the other metals reſpectively, except the manufacture of *Tin-Plate*, which may be here mentioned.

Tin-Plate or *Tinned Iron* (*Fer Blanc* of the French) holds an intermediate place between an alloy and a coating. It is made ſimply by immerſing plates of iron into melted tin, whereby they not only become covered with a perfect coating of this metal, but a very intimate union of the two metals takes place, to a certain depth in the ſubſtance of the iron, which is ſeen by cutting it tranſverſely, and when the tinning has been repeated two or three times the whole plate is more or leſs alloyed, or as it were ſoaked with the tin.

Tin-plate is manufactured in ſeveral countries, but no where to ſuch perfection as in England, to judge by the quantity exported. The fineſt kind when highly poliſhed has a luſtre and whiteneſs ſcarcely inferior to ſilver, and the peculiar excellence of the Engliſh plate appears to be chiefly owing to the perfect ſmoothneſs given to the plate before tinning, and the great uniformity in the application of the metallic coating.

The general proceſs is extremely ſimple, and is thus deſcribed by Mr. Donovan.[y]

It is carried on near Caermarthen in South Wales, the centre of an immenſe and increaſing manufacturing diſtrict of many of the moſt important metals.

The iron ore employed in this manufactory is the common kind of the country, intermixed with a large portion of the fine hæmatite from Ulverſtone in Lancaſhire, which gives a very fine metal. This too is ſmelted with *charcoal* inſtead of coke, to produce a metal of the greateſt purity and extenſibility, and cloſeneſs of texture, which qualities are particularly required in this manufacture. The reduced ore is ſmelted in the uſual manner and caſt into pigs, which are then wrought by the hammer into long flat bars, that are afterwards cut into pieces of about ten inches in length. Theſe are then wrought into plates by being heated red-hot, and paſſed through a flatting-mill which conſiſts of two large cylinders of ſteel, caſe-hardened and ſecured in a frame of iron. Theſe are placed contiguous to each other but with a certain interval of ſpace, and revolve in a contrary direction, ſo that when one end of the bar is thruſt in the ſpace between the cylinders, the whole is drawn through and proportionably extended and flattened in the paſſage. The diſtance between the cylinders, which of courſe determines the thickneſs of the plate, is maintained and regulated by ſcrews which can be altered at pleaſure. When the bar is thus made into a plate of twice the thickneſs of the ordinary plates it is heated red-hot, cut in two by a pair of ſhears, and one piece folded exactly over the other, and both repaſſed repeatedly through the cylinders till the folded plate has extended to the ſame length and breadth as the plate was before cutting. It is then clipped round the edges and the two plates torn aſunder (which requires ſome little force) after which they are each finiſhed by paſſing through a finer rolling-preſs, ſo as to take away every creaſe or inequality in the plate, and thoſe that are too rough to paſs through this finer preſs are thrown aſide.

The plates are then ſteeped in a very weak acid liquor, and when taken out are ſcoured thoroughly with bran ſo as to be quite bright and poliſhed to enable the tin to adhere. The tin is melted in deep rectangular crucibles, and kept fluid by a moderate charcoal fire beneath. To prevent its calcination a quantity of greaſe prepared from linſeed-oil and ſuet is conſtantly kept floating on the ſurface of the tin and renewed as it evaporates off, which gives an exceſſively nauſeous ſtench. The plate is then taken up by one corner by a pair of pincers and dipped vertically into the tin, and when withdrawn is found beautifully white and reſplendent with the coating of this metal that adheres to it. This dipping is repeated three times for what is called *ſingle tin plate*, and ſix times for the *double plate*. The plates are then only cleanſed and ſorted, and are fit for uſe.

Some further particulars may be added from other authorities.

In many manufactories the iron plates before tinning are cleanſed by being immerſed in large barrels full of a mixture of rye-flour and water, ſometimes with verjuice which by fermentation has become very acid. In Bohemia[z] the plates remain three times twenty-four hours in tubs filled with this aceſcent mixture, in three different ſtates, after which they are waſhed, ſcoured with ſand and water, and kept under water till juſt before they are uſed, to avoid ruſting again.

Attention is to be paid to the heat of the melted tin; if too hot, the plate comes out yellow. The plates are immerſed quite wet into the melted tin, paſſing in their way through

[y] Deſcriptive Excurſions through South Wales in 1805, vol. 2, p. 194.

[z] Jars Voy. Min. 6 Mem

the melted ſuet which covers it. Juſt before dipping, ſome water is thrown on the melted ſuet, which cauſes a violent ebullition and makes the ſurface of the metal quite clean and bright. The plates when tinned are ſet up to drain, by which a number of drops of tin collect in ſmall knobs at the lower part. Theſe are taken off by a ſecond immerſion into a ſeparate cauldron of tin, but only to the depth of a few inches, by which the drops of tin melt down and the whole tinning is made more uniform in thickneſs. They are then cleanſed with a rag and ſaw-duſt or bran. About 19½ pounds of tin are required for 300 plates, meaſuring 1 foot by 9 inches.[a]

The manufacture of tin-plate in France appears to be conducted ſo nearly in the ſame manner as not to require a ſeparate deſcription.

In the manufactures of tin-plate on the continent a quantity of copper is aways added to the tin, but in very ſmall proportion. The exact quantity is regulated by ſlight circumſtances, which only experience can teach. It appears to be in general from $\frac{1}{80}$ to $\frac{1}{120}$ of the tin. The copper prevents the tin from adhering in too great a quantity to the iron, and cauſes the ſuperfluous part to drain off more freely. Too much copper gives a dull yellow tint.

It appears that the method of flattening the bar into plate by cylinders is only adopted in this country, but in other places is done by the hammer.

The affinities of the oxyd of iron for the reſpective acids are in the following order: the gallic, oxalic, tartareous, ſulphuric, muriatic, nitric, phoſphoric, arſenic, fluoric, ſuccinic, citric, acetic, boracic, pruſſic, and carbonic acids.

ISERIN. See TITANIUM.

ISINGLASS. See GELATIN.

[a] Encycl. Arts & Metiers. art. Ferblantier.

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